World Soils Book Series

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The Soils of Bangladesh

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International Union of Soil Sciences

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Dedicated to the farmers of Bangladesh who have made the best use of knowledge on Soil to make the country self sufficient in food

Preface

Bangladesh is a very small country with only about 15 million hectares of land but it has to take care of more than 150 million people, providing habitation and food. The actual land:person ratio is ever-shrinking and the amount of land available to a person now stands at less than 0.05 ha. This has forced soil scientists to devote much attention to a better understanding of this natural resource so that increased food could be produced using the best inputs. As a result terms such as *sustainable soil management*, *food security*, and *soil resilience* have been the most pronounced and discussed topics during the last decade. If the term *sustainable* means "the same forever," then the meaning of sustainability will be of little interest as the population of the country has already become unbearably large and is already putting a lot of pressure on soils. Sustainability for Bangladesh could be seen as gradual improvement and simultaneous maintenance without further degradation over a long period of time. The challenges to sustainable land management in Bangladesh are twofold. The first is to boost crop production and to maintain the production level while maintaining the soil quality of the agricultural lands and second, to alleviate the already degraded lands in such a way that these lands are improved to an environmentally sustainable and acceptable quality. For food security the country has to restore sustainable agriculture. One of the key elements in sustainable agriculture is the greater efficiency of resource use. Soil resilience relates to the ability of soil systems to return to their original state after the withdrawal of stress that soil undergoes during soil management. The stresses could generate from natural as well as anthropogenic operations. In fact, soil resilience is thought to be the balance between soil's restorative and degradative stages. The processes that are thought to be important for soil resilience are (a) maintenance of soil organic matter content; (b) improvement in soil physical and chemical properties; (c) maintenance of soil biodiversity; (d) reduction in soil degradation; (e) control of soil erosion rates below the soil formation rate; and (f) increase in nutrient reserve and recycle mechanisms (Hussain et al. 2002).

For a densely populated country such as Bangladesh with a gradual increase in population and scarce and shrinking land, the terms sustainable land management, food security and soil resilience do carry a positive meaning. The soil scientists of this country have been working quickly to achieve and materialize these over the last hundred years or so.

In as much as the livelihood and economy of this part of the Indian subcontinent depended on agriculture, the relevant scientists used and manipulated the soil to increase productivity without giving much emphasis to soil properties. However, as pressure for increased food production mounted due to population growth, soil scientists started looking deeper into the soils of the region and initiated a systematic study of the soils. Soil survey, soil classification, rational use of chemical and biological inputs to the soil, and the like emerged as priorities.

This book is a compilation of existing knowledge of the soils of Bangladesh. The book has been organized in such a manner that any person interested in the utilization of

soil could make use of it. The chapters include a brief introduction, a history of soil studies in this part of the Indian subcontinent, the geomorphology, physiography, soil classification, soil fertility, and information on the problem soils of the country, as well as land use and soil management practices. Human intervention and soil degradation are also the subject of a chapter. Possible research priorities, administrative policies, and other actions that are needed for maintaining quality soil for future generations have been dealt with in the last chapter.

The authors wish to acknowledge the director of the Soil Resources Development Institute (SRDI) for his cooperation in providing the relevant information and documents and according permission to use them in the book. The senior author is particularly thankful to A. F. M. Manzurul Hoque of SRDI for his omni-availabilty for any discussion on soil classification-related matters whenever sought. We are also indebted to Sajal Roy, M. T. A. Chowdhury, and Nadia Noor for their help in the typing and other technical effects of the manuscript.

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Contents

1 Introduction

Bangladesh is located in the northeastern part of South Asia between 20°34 and 26°38 north latitudes and 88°01 and 92°41 east longitudes. The country is located as an interface of two different environments: the Bay of Bengal in the south and the Himalayas in the north (see Fig. 1.1).

It is bordered on the west, north, and east by India, on the southeast by Myanmar, and on the south by the Bay of Bengal. Bangladesh has an area of 147,570 sq km (57,977 sq miles). The territorial water limits are 12 nautical miles. The economic zone is 200 nautical miles of the high seas from the base lines. The territorial sea (TS), the exclusive economic zone (EES), and the continental shelf (CS) cover an area of 207,000 sq km. Bangladesh is the world's largest deltaic country and is formed by the three great rivers of the Brahmaputra, the Meghna, and the Ganges. Of the total land area, about 14 million hectares are land surfaces and the remainder is constituted of rivers and inland water bodies. It is a low-lying riverine country. More than 85 % of the area of the country is flat alluvial plain criss-crossed by the rivers and their innumerable tributaries and distributaries that number about 230 (BBS 2008).

The country is situated in the subtropical zone and sits astride the Tropic of Cancer where the climate is a humid tropical monsoon type with three distinct meteorological seasons of summer, monsoon, and winter. The main characteristics of the climate are high temperatures, heavy rainfall, and excessive humidity. The winter is short, mild, and dry and spreads from November to February. The summer rainfall ranges from 1,500 mm in the northwest to 5,000 mm in the northeast. The winter rainfall averages about 300 mm. The rainfall along with depth and duration of flooding is the main critical factor for agriculture in Bangladesh. The most crucial aspects of rainfall in relation to the use of land for agriculture are related to the uncertainty of the onset and departure of the monsoon as well as the occurrence of droughts.

Bangladesh is one of the most disaster-prone areas of the world. The low-lying delta regions of the country are subject to different degrees of flooding from monsoon rains, cyclones, and tidal waves with major crop damage and high loss of lives. The Sundarban mangrove forests in the south of the country serve as a natural defense against cyclonic storms and tidal surges (Choudhury 2008).

The country is densely populated with more than 150 million people. Bangladesh has the seventh largest population in the world and a very high population density in what is basically an agrarian economy. Despite a declining trend of its share in overall gross domestic product (GDP) from 31.2 % in 1985–1986 to about 20 % in 2010–2011 mainly due to the rapid expansion of industry and service sectors, agriculture remains the major source of income for the rural poor in Bangladesh. About 60 % of the total population and 48 % of the total labor force depend on agriculture and related farm and nonfarm activities for their livelihood. As a result, the soils of the country have been and still are one of the natural resources that has been given much attention.

The importance of agriculture in the Bangladesh economy can be ascertained from the facts that in the world, Bangladesh ranks first in terms of arable land as a percentage of land area; first in terms of agricultural raw material imports as a percentage of total merchandise imports; and fifth in terms of rice production, rice consumption, and area under rice production (see Table 1.1). It ranks high in terms of fertilizer consumption and percentage of irrigated land. In South Asia, Bangladesh ranks first in terms of cereal yield and fertilizer use per hectare.

Although small, the soils of Bangladesh are quite varied. So far, more than 465 soil series have been identified. This wide variation in soils is due mainly to the physiography and partly to microclimatic variation. Although a majority of the country's soil is developed on alluvial deposits, there are also hilly formations, and soils formed under evergreen and/or deciduous forest vegetation. In fact, the whole country has been subdivided into seven physiographic units. Soils developed under each of these units are identified with

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Table 1.1 Ranks of various parameters relating to Bangladesh agriculture in the world

Items	Units	Value	Rank out of countries considered
Total area	'000' sq.km	148	[99th of 248]
Population in 2008	Million	153.5	[7th of 240]
GDP (PPP adjusted) in 2010	US$ billion	259	[46th of 227]
GDP per capita in 2006	US$	429	[183rd of 207]
Arable land	Million hectares	7.96	[16th of 199]
Arable land as percentage of land area	Percentage	61.11	[1st of 199]
Area under rice	Million hectares	10.9	[5th of 23]
Irrigated land	Percentage of cropland	56.12	[15th of 164]
Land under cereal production	Million hectares	11.78	[14th of 176]
Imports of agricultural raw materials	Percentage of merchandise imports	8.81	[1st of 155]
Cotton imports	Thousand bales	1,025	[12th of 109]
Cotton production	Thousand bales	70	[39th of 109]
Fertilizer consumption (per capita)	Grams per hectare	1,780	[34th of 169]
Fertilizer consumption (Total)	Million metric tons	1.42	[20th of 169]
Rice consumption	Million metric tons	26.4	[5th of 17]
Rice production	Million metric tons	26	[5th of 16]
Agriculture labor	As percentage of total labor force	54.7	[44th of 149]
Agriculture value-added, annual growth rate	In percentage	2.21	[79th of 164]
Workers per hectare	Number	4.6	[2nd of 148]
Yield of rice	Tons per hectare	3.6	[14th of 23]
Yield of wheat	Tons per hectare	2.21	[17th of 26]

Source Ministry of Agriculture, GoB (2012)

them. For example, soils could be Himalayan piedmont soil, hill soils, acid-basin clay soils, calcareous alluvium soils, noncalcareous alluvium soils, peat land soils, mangrove soils, and so on.

Due to this variation in soil formation, the land use pattern is also varied. Land use in Bangladesh is controlled by: (1) land types, which are classed as VH, H, MH, ML, to L depending on how many months and how deeply they are inundated during the seasonal flooding periods; (2) soil types; (3) local climatic conditions; and (4) farmers' economic capability (including whether he or she can pay for the irrigation, high yielding seeds, and requisite agrochemicals). However, most of the lands are either double-cropped (28.5 % of the total cropped area/50.1 % of the NCA) or single-cropped (21.1 % of the total/37.1 % of NCA) with a small proportion of the land given to triple-cropping (7.3 % of the total/12.8 % of NCA). Wetland rice cultivation occupies the major single-cropped lands. Cropping intensity is more than 180 %.

The whole of the country has been divided into 30 agro-ecological zones (including many subzones) considering the diversity of soil types and also of the microclimatic variations allowing growers to select the crop on the basis of soil test results. A detailed cropping pattern for each of the zones and subzones has been developed with requisite fertilizer recommendations. This is updated every four to five years. The soil databank is one of the richest in the region.

1.1 Constraints

The major constraints of Bangladesh soils as regards its general fertility and health are briefly discussed herein.

1.1.1 Soil Reaction

The average pH of Bangladesh soils could be taken on the acidic side of the pH scale, between 5.5 and 6.5. The Gangetic alluvium soils, particularly the calcareous ones, have pH greater than 7.0, reaching at times up to 8.5. These are, however, not alkaline. These contain free carbonates and bicarbonates. Soil plateaus, raised lands, and hills are usually acidic in nature. Because of pH variations, the nutrient availability, particularly that of P and some micronutrients, are affected. Otherwise, lowland rice cultivation is not affected by soil reaction, as the pH tends to come to a value of around 7.0 on submergence. Liming is needed in soils having pH less than 4.5, which is more prominent in tea soils and hill soils. Upland crops are adapted to local soil pH.

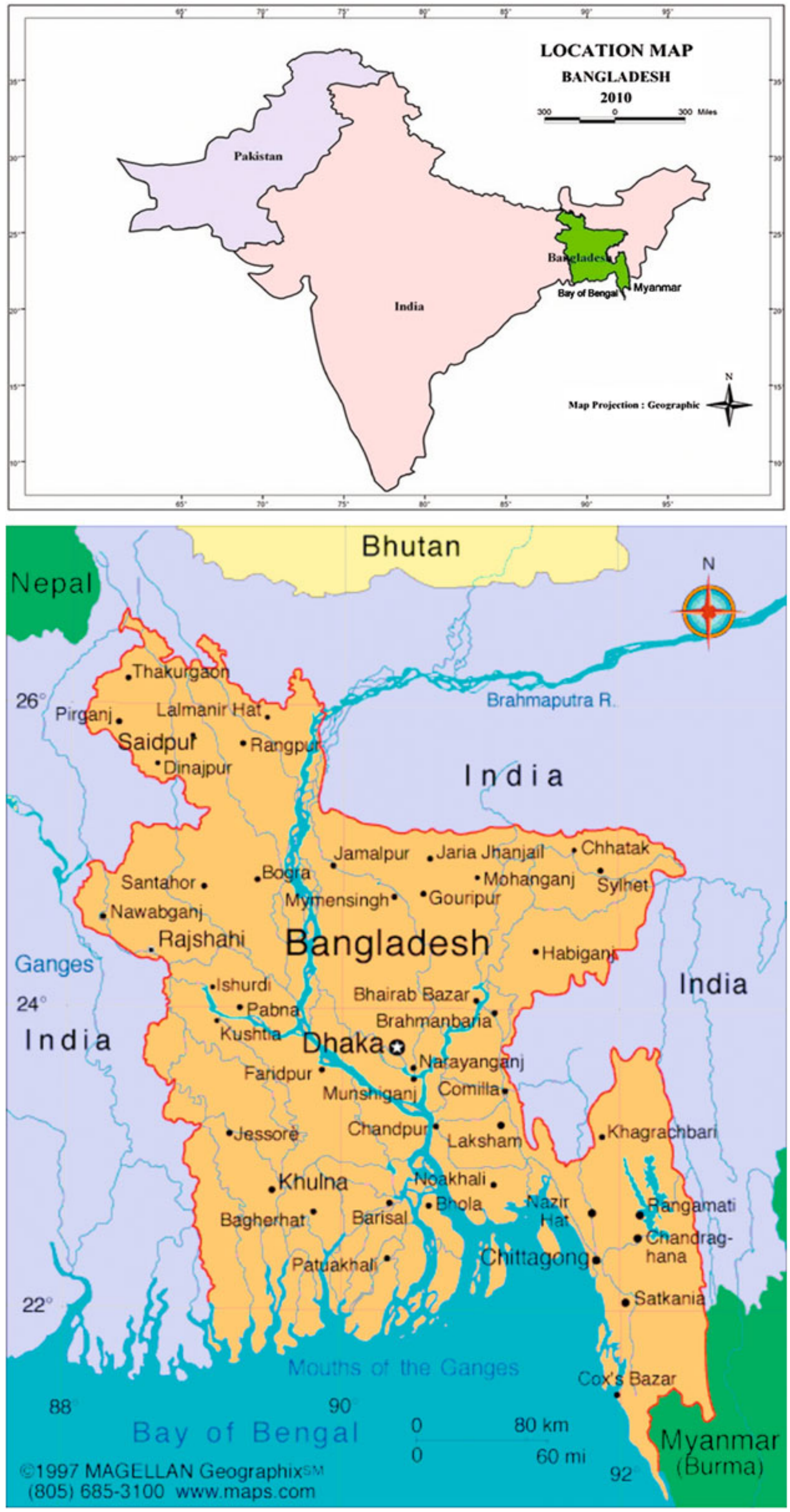

Fig. 1.1 Map showing the location of Bangladesh in South Asia (*source* SRDI and web)

1.1.2 Organic Matter Status

The organic matter status of Bangladesh soil is one of the poorest in the world. The average OM content of Bangladesh soils is less than 1 % ranging between 0.05 and 0.9 % in most cases. Soils of peat lands and some low-lying areas usually contain OM higher than 2 % on average. The OM supply in soil is one of the major constraints of agriculture in the country. Yet, Bangladesh has been producing bumper crops, and cereal production in 2000 exceeded 27 million

tons with a surplus of 9 million tons. This has been possible only due to the use of high doses of inorganic fertilizers and an improved variety of seeds. Most of the Bangladesh soils show improved response when OM is incorporated along with inorganic fertilizers. The recommended doses vary between 5 and 10 tons ha^{-1} of fresh or partially decomposed cow dung. Use of green manuring plants such as *Sesbenia rostrata* is also encouraged. Use of compost is absent or insignificant.

1.1.3 Nitrogen Status

Because of the low level of OM the nitrogen status of Bangladesh soils is substantially low and most crops on all soils respond to N-applications. In fact, N-fertilizers occupy the major fertilizer being consumed in the country. The country has as many as six fertilizer factories producing mostly urea using natural gas. An increase of two- to threefold is common in most crops including rice with N-fertilizers over no fertilizers. The N-fertilizer consumption during 2006–2007 was more than 2.7 million metric tons.

1.1.4 Phosphorus Status

The available P in Bangladesh soils could be considered between low to medium. Most soils respond to P-fertilization. P availability is pH dependent. The source of P supply in soils is inorganic fertilizer. This again, is not proportionate to the supply of inorganic N. The TSP, SSP, and DAP consumption in 2006–2007 was only 577,000 metric tons. Many soils fix applied P. The recovery rate is 30 % on average by the first crop.

1.1.5 Potassium Status

Bangladesh soils are not deficient in potassium although many soils are found to respond to K-fertilization. Mainly these are nonalluvial soils and the coastal saline soils. The critical limit for NH_4OAc extractable K in Bangladesh soils for rice is considered to be 0.4 meq %. Soils high in 2:1 expanding lattice clays (illites, chlorites, and montmorillonites) fix applied K. Although the coastal saline soils have K content higher than 0.4 meq %, it is the high Na content that makes them K responsive.

1.1.6 Sulphur Status

Response to S application is common in most soils except coastal saline soils, acid-sulphate soils, and some acidic soils. Irrigated crops in the northern districts respond markedly to S application. About 4 million ha of land are supposed to be S-responsive. Gypsum is the principal source of sulphur. An application rate of up to 20 kg ha^{-1} is recommended in many places for most crops.

1.1.7 Zinc and Boron

During the recent past, soils, particularly those under constant water logging and irrigation have been found to respond to Zn and boron applications. The calcareous flood plain soils are among them. About 1.7 million ha of land have been estimated to be deficient in Zn supply. The recommended rates for Zn application are up to 5 kg ha^{-1} in the form of either ZnO or $ZnSO_4$ and that for boron is 2 kg ha^{-1}.

1.1.8 Other Micronutrients

Response to micronutrients other than Zn and B has not yet been reported in any soil for any particular plant. However, it is doubtful that in some peat, land soils, and other soils, Mn application might lead to a positive response. It has not yet been confirmed.

1.1.9 Soil Salinity

A vast coastal area is subjected to seasonal salinity. The salinity is mainly of $Cl–SO_4$ type. As it is caused by marine water intrusion, the Ca:Mg ratio in the coastal saline soils is less than 1.0, which creates severe fertility problems. Most lands in saline areas are under a single crop. Application of K-fertilizers up to 60 kg ha^{-1} has been found to increase crop yield substantially.

1.1.10 Problem Soils

The extent of problem soils in the country is substantial. These include soils with high acidity, highly saline soils, soils with high erodibility, and soils in the depressions. Soils with very low organic matter content are also considered problem soils. These soils need special soil–water–fertilizer–crop management practices to make them productive.

1.1.11 Contaminants

At present arsenic is considered to be the single most important contaminant in Bangladesh soils. The source of As in the groundwater is geogenic. The depth of As-laden groundwater is variable depending upon the depth of the layers containing oxidizable or reducible As-containing minerals. Soils irrigated with As-laden water are being

contaminated with the element. Accumulation of As on the upper horizons is also likely to occur through the capillary rise of water during lean periods. Although the average values obtained for As in soils are less than 10 mg/kg, values as high as 58 kg/ha have also been obtained from regions where groundwater irrigation is practiced.

Soils are also being contaminated by Pb, Cd, Cr, and many organics. These mainly occur around the industrial belts and sewage disposal areas in the peri-urban areas. Motor vehicle exhausts have also been contributing to substantial lead accumulation in agricultural lands.

Disproportionate use of nitrogenous fertilizers sometimes leads to NO_3 pollution in the ground- and surface water. Accumulation of pesticide residue is another source of contamination, which, although not marked, cannot be ignored, and needs to be properly and timely addressed.

1.1.12 Misuse and Abuse of Soils

It is high time for our planners and policy makers to frame rules/laws to protect the arable soils from ruination. Many agricultural lands have been urbanized or industrialized. One can find numbers of brick kilns set up on fertile agricultural lands along the highways. As these lands are privately owned, the government has practically no control over the appropriate use of the lands. Forestlands are also brought under urbanization and industrialization. Only about 7 % of the total land area is under forest cover now. Overexploitation, that is, using the soil for intensive cultivation without replenishing it, is causing nutrient mining to an extent that ultimately will make it barren. Greed mingled with lack of farsightedness, proper awareness, and absence of punishable laws has aggravated the misuse and abuse of the limited land that is taking a heavy toll on our soils.

1.2 The Possibilities

Given all these constraints, Bangladesh has recently been striving forward with its cereal and other crop production. Production of rice, the main food item of the country increased fourfold since 1972 and reached 33.50 million tons in 2009–2010 making Bangladesh almost self-sufficient in this principal food grain. The target is to reach a production level of 35.50 million tons by 2015–2016. Crop intensity has increased from 148 to 181 %. The increase in rice production has been possible largely through an increase in yield from 1.05 to 2.2 tons ha^{-1} as a result of adoption of HYV seeds, application of irrigation, fertilizer, development of rural infrastructure, market, inputs, subsidies, and the like. The soil scientists of the country have been playing a vital role in this endeavor. Agriculture is one of the few sectors in the country that can boast a success story.

This again, makes one ponder about the quality of the soil for future generations. Soil health needs to be improved and for that reason organic matter incorporation has to be accentuated coupled with the rational use of agrochemicals. The misuse and abuse of our land resources needs to be minimized at the same time. Remediation measures need to be undertaken to abate the possibilities of human and ecosystem health risks likely to occur through soil–crop transfer of major soil contaminants.

Keeping all these points in view, this book has been compiled by a nonpedologist soil scientist. The items in this book have been chosen in such a manner that it becomes easier for a person dealing with soil science but at the same time the book is not overly concerned with soil morphology, soil taxonomy, or soil classification.

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2 History of Soil Research in Bangladesh

On the basis of the report of the Famine Commission of 1901, set up by the Viceroy Lord Curzon, research in agriculture was initiated in what was then called Bengal around the beginning of the nineteenth century. Agricultural Research Laboratories and an experimental station at the periphery of Dhaka were established in 1905 when Dhaka was the capital of East Bengal and Assam. It is thus assumed that soil investigation in this part of British India started around 1905. Soil science as an academic discipline and as a strong arm of the process of agricultural development had its humble beginning during the early 1940s. During the British India period research on soils was carried out in the chemistry department of the University of Dhaka and in the agricultural chemistry section of the Agricultural Research Laboratory under the Directorate of Agriculture of Bengal. At the University of Dhaka, research on soils was initiated by Professor and later Sir G. C. Ghosh under the chemistry department with the occasional grant from the Imperial Council of Agricultural Research as part of different research projects. Students could carry out research in soil-related problems for their MSc degrees in chemistry. At a later stage soil science was included as one of the fourth papers for the BSc (Honors) examination in chemistry. By 1938, the University of Dhaka had a number of famous soil scientists including Dr. P. K. Dey, Dr. S. P. Roy Chowdhury, Dr. M. O. Ghani, Dr. A. T. Sen, Dr. J. N. Chakraborty, and Dr. T. P. Banerjee as teachers, and Dr. B. C. Dev, Dr. M. Sulaiman, and Dr. M. K. Mukherjee as doctoral research students (Islam 1995).

Many fundamental contributions to the development of soil science were made by the University of Dhaka. Some of these contributions include N_2 fixation by BGA in paddy fields, biochemistry of water-logged soils, red lateritic soils of India, methods for dispersion of soils for mechanical analysis, base exchange, phosphate fixation, clay colloids, and the like. The flourishing condition of soil investigation work at the University of Dhaka continued up to 1947, when after the partition of India, senior Hindu teachers left the country and teaching and research in soil science in the chemistry department met a serious setback.

An important development during the early Pakistan period was the creation of the Department of Soil Science at the University of Dhaka in 1949 at the initiative of Dr. M. O. Ghani who was serving as agricultural chemist to the government of what was then East Pakistan. The department soon became one of the major departments of the university and students were admitted to 2-year BSc and 2-year MSc courses. At that time this was the only full-fledged department of soil science in any university in the whole Indian subcontinent. The 3-year BSc (Honors) and 1-year MSc courses started in 1963. Most of the soil-related activities in Bangladesh (then East Pakistan) until the 1963 creation of a soil science department at the Agricultural University have been contributed by the soil scientists produced from the Department of Soil Science of the University of Dhaka. Later on, since the independence of the country, in addition to the creation of a few agricultural universities, a number of general universities opened their own departments of soil science. Most of the soil-related research carried out in the university departments, particularly at the University of Dhaka, pertained to basic and quasi-basic activities. The Department of Soil Science at the University of Dhaka was renamed the Department of Soil, Water and Environment in 2000.

The research in isolated soil units that was being carried out for a long time as mentioned earlier was mainly concerned with soil fertility and took a soil chemistry perspective. Scientific attempts to study Bangladesh soils from the pedological aspects were initiated by the middle of the last century. The history of soil genesis, soil morphology, and soil classification in Bangladesh is not very old. The legacy data on soil profiles may only be 50 years old. The main driving force for a systematic study of the country's soils was to understand the properties of soils in order to enhance their agricultural productivity to cater to the needs of the ever-expanding population with a very limited land resource. Basic information on the soils of the country was lacking in the initial stage that made the possibility of a natural classification of the soils difficult. At different times several authors attempted

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classification of the country's soils on the basis of pedogenic factors that were basically technical systems. The real beginning of systematic collection of soil information was initiated in the 1960s with the Soil Survey Project of Pakistan, the predecessor of the present Soil Resource Development Institute (SRDI) of Bangladesh. The Department of Soil Survey was established in 1961 as a project under FAO/UNDP and the government of Pakistan to carry out a reconnaissance soil survey of the country. The follow-up activities of the project were continued by the Central Soil Research Institute from 1969. After the emergence of Bangladesh, the project was named the Department of Soil Survey under the Ministry of Agriculture and in 1983 the government reorganized and expanded this department into a full-fledged institution and named it the Soil Resources Development Institute (SRDI). This institute, however, is not a research institute as such but a service-oriented organization. The project activities of the Department of Soil Survey expanded to include the interpretation of soil survey data to answer the needs of various users and to study certain field properties of soils required to characterize soil behavior more precisely. The reconnaissance soil survey was completed in 1975 and from 1975 onwards, detailed soil surveys have been carried out by SRDI for various clients.

Islam and Islam (1956) first tried a technical classification of the soils of this country and attempted to describe the landscape and soils by dividing the country into seven soil tracts without much field investigation. This classification scheme was subsequently known as the seven soil tracts system of classification, the basis of which was the physiographic condition and also the geological origin of the parent materials of the soil tracts. In the case of coastal soils, their chemical characteristics were taken into consideration. The seven soil tracts are as follows (the details of these tracts are described in Chap. 8).

1. Madhupur tract
2. Barind tract
3. Tista silt
4. Brahmaputra alluvium
5. Gangetic alluvium
6. Coastal saline tract
7. Chittagong hill tract

As per this classification, the Pleistocene terraces have been divided into two tracts (Madhupur and Barind) even though their materials are the same and lie mostly above the flood level. The floodplains have been divided into four tracts based on the rivers from which the materials were derived. The sediments of the Ganges River are calcareous, whereas those of the other three rivers are noncalcareous. The coastal saline tract is tidally affected and the soils are saline. This classification is a very simple and generalized one and for the first time depicted the general distribution of the soil tracts of Bangladesh that could be understood even by a nonsoil scientist. It was, however, not a natural system of classification inasmuch as it was based on pedogenic factors such as parent materials and physiography and not on soil properties. This classification scheme has been a good attempt to classify the soils of Bangladesh when practically no information on the country's soils was available (Hussain et al. 2003).

To assess the efficiency of precipitation for biological activity and soil leaching by taking into account the evaporative power of the air as measured by the evaporation from free water surface or by the atmospheric deficiency in humidity, Karim and Hossain (1957) calculated some climatic indices for the country and came out with pedoclimatic zones of Bangladesh. These are: (a) humid, (b) semi-humid, and (c) feebly arid. It was considered that climate is the most active pedogenic factor. A pedoclimatic zone was defined as representing an area where the climatic factor working on parent material has produced similar soils. The introduction of the climatic zonality concept was a new approach in distinguishing the different pedoclimatic zones occurring in the country. The division into pedoclimatic zones was an attempt to predict the probable occurrence of soils; this zoning could be compared to the much-used agroclimatic zones (Karim and Hussain 1957).

Albeit having many shortcomings, this classification was a serious scientific attempt for the delineation of the pedoclimatic regions of the country; the inherent ideas of this classification served a very useful purpose when very little field information was available (see Fig. 2.1).

Considering the fact that most of the soils in this country are relatively young and their properties are largely influenced by the nature of the parent materials and drainage conditions, in 1964 Brammer emphasized that knowledge of geomorphology of Bangladesh is essential for a proper understanding of the nature and distribution of the soils. Accordingly, on the basis of three distinct sediments—Tertiary, Pleistocene, and Holocene—that occur in Bangladesh, Brammer (1964) divided the country into 15 physiographic units and described the properties of each in relation to the soils that have formed on them. Each physiographic unit contains certain well-defined soils. As such, this division has been considered a soil classification for the country. The units are as follows.

1. *Consolidated Tertiary Rocks*
   (a) Chittagong and Tippera Hills;
   (b) Shillong plateau margins.
2. *Unconsolidated Tertiary and Pleistocene Sediments*
   (a) Mainly coarse-textured sediments
      (i) Low western ridges of Chittagong Tripura Hills;
      (ii) Lalmai Hills;

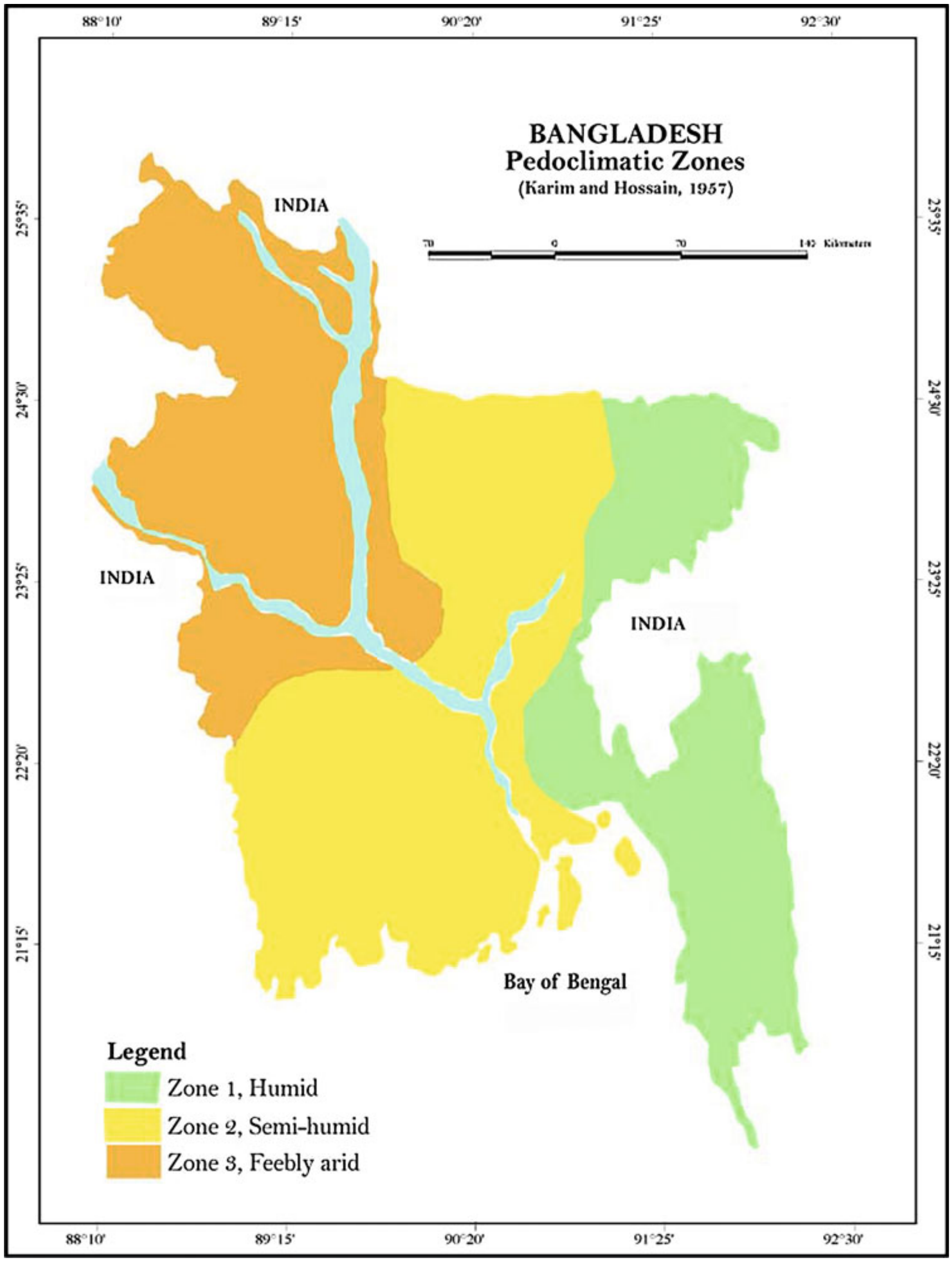

Fig. 2.1 Pedoclimatic zones of Bangladesh (*Source* SRDI)

(iii) Sylhet and Chattak Tillas;
(iv) Shillong Plateau Piedmont Hills.
(b) Mainly fine-textured sediments
(i) Madhupur Jungle Tract;
(ii) Barind Tract.

3. *Recent Alluvial Deposits*
   (a) Himalayan piedmont alluvial plain;
   (b) Tippera surface;
   (c) Moribund Ganges delta;
   (d) Recent deltaic flood plain;
   (e) Sylhet basin;
   (f) Coastal saline zone;
   (g) Tidal mangrove swamp.

- This classification is in fact an elaborative version of the seven soil tract classification system. However, the introduction of a few new names made it a newer classification. Like the previous classifications, this classification also focused limited attention on soil properties. The information on land and soils of Bangladesh published from 1956 to 1964 were of no significance in practical use because these were produced without much field investigation. Systematic generation of primary data regarding land and soil resources started during the early 1960s by undertaking the Reconnaissance Soil Survey (RSS) program under the Soil Survey Project of the then East Pakistan with

the active cooperation of the FAO. The information contained in the RSS reports, a comprehensive classification of Bangladesh soils was carried out by Brammer in 1971. Through this descriptive classification, the classification of the soils in Bangladesh was made understandable to the layman. Brammer called it the General Soil Type (GST) system of classification (FAO 1971). A GST was defined as a "group of soils formed in the same way and having a broadly similar appearance."

- The RSS was based on intensive aerial photo interpretation followed by field examination of soils made along planned traverses across the landscapes. A total of 465 soil series (taxonomic units) were identified, described, and classified particularly for the agroservice purpose through the RSS from 1965 to 1976. Soil series were identified on the basis of differentiating characteristics such as texture, nature of the horizon developed, soil reaction, and consistency, among others. The physical and chemical properties of 465 soil series were determined in the laboratory and all the analytical results were subsequently published in 33 RSS reports. Soils were mapped at the scale of 1:125,000 in terms of geographical associations or complexes of soil series and phases. A total of 1,034 soil associations (groups of soils that occur together within part or all of a physiographic unit or subunit) were mapped. The smallest soil series has an area of only 11 ha and the largest one has an area of 486,493 ha. The average area of a soil series is 23,989 ha. The total covered area in the RSS was 11,466,913 ha. Forests occupying 15 % of the land in Bangladesh have not been covered by RSS. The RSS in Bangladesh successfully filled the vacuum that had existed for a long time. Through the RSS people could get first-hand information about the soils of Bangladesh. Through their characterization in soil taxonomy, everybody could have some knowledge of the nature of Bangladesh soils. Some basic soil properties such as their morphological, physical, and chemical properties were made available (Imamul Huq and Hoque 2012).
- The GST system offers a single category of 21 soil types with no higher or lower category. Originally 17 GSTs were proposed but the number was increased to 21 in a subsequent revision (FAO-UNDP 1988; see Chap. 5). The information contained in the RSS reports was utilized in making the AEZ map of Bangladesh (FAO-UNDP 1988). Soils (taxonomic units) were classified according to two international soil classification systems: the US soil taxonomy and the FAO-UNESCO legend based on RSS data. RSS-based information has been used as the baseline data to conduct the semi-detailed soil survey of the country from 1986 to 2001 and the publication of the *Land and Soil Resource Utilization Guide* for upazilas (subdistricts) of the country.
- FAO-UNDP developed a General Soil Map on the basis of Brammer's classification at the time of making a "Land Resource Appraisal for Agricultural Development of Bangladesh" in 1988. This map is shown in Fig. 2.2.

Later in 1997 SRDI developed another General Soil Map of the country on the basis of RSS data and further field verification (See Fig. 2.3). For details see Chap. 5.

The land resources appraisal (LRA) for agricultural development in the country was published in 1988 (FAO-UNDP 1988). Based on the RSS data on land types and soils, physiography, and climate, a database for the land resource appraisal was prepared with the objectives (a) to compile a national computerized land resources database; (b) to develop and establish a computerized land and climate resources appraisal system; (c) to differentiate and delineate agroecological regions (see Chap. 3); (d) to assess the crop production potential of the land and climate resources under rain-fed conditions; and (e) to make the land resources database and crop suitability assessments available to agricultural and forestry researchers and extension and development planners. The LRA has been published in the form of seven reports including an executive summary. The soil series identified through RSS, according to the US soil taxonomy, comfortably fit into five orders, including: Inceptisols, Entisols, Ultisols, Histosols, and Mollisols. There were 12 suborders, 21 great groups, and 56 subgroups in this country (Hussain 1992). According to the FAO-UNESCO soil classification system, the soil series identified through RSS has been categorized mainly into 35 FAO-UNESCO soil units. These occur mainly as Fluvisols, Gleysols, Leptosol, Arenosol, Cambisol, Luvisol, Planosol, Alfisol, Histosol, and Anthrosol. The soils of Bangladesh have never been classified at the "Family Level."

Although RSS was conducted to generate land and soil data for agroservice purpose, the use of these data was limited only to planners and researchers. RSS data could not be widely used at the farmers' level. Considering this issue, Soil Resource Development Institute (SRDI) undertook the program of a semi-detailed soil survey particularly to publish the *Land and Soil Resources Utilization Guide* for different upazilas of the country in 1985. Through the semi-detailed soil survey a huge database of information on land and soil resources of the individual upazilas was collected, soils were mapped at the scale of 1:50,000 and grouped in terms of their similarities in physicochemical properties and physiographic and AEZ-based distribution. About 50,000 topsoil samples collected for 324 soil groups during the semi-detailed soil survey were analyzed in the laboratory to

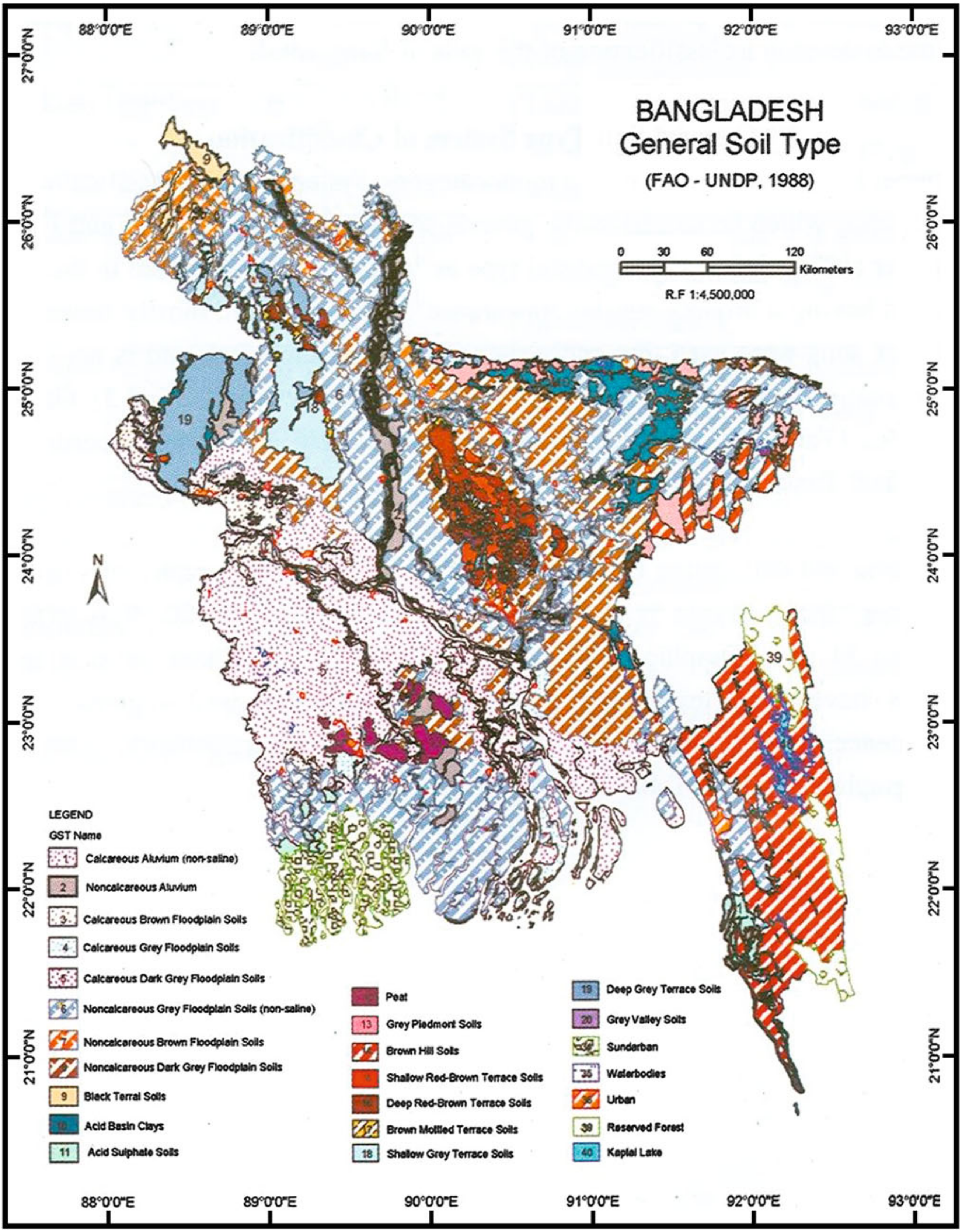

Fig. 2.2 General soil map of Bangladesh done in 1988 (*Source* SRDI)

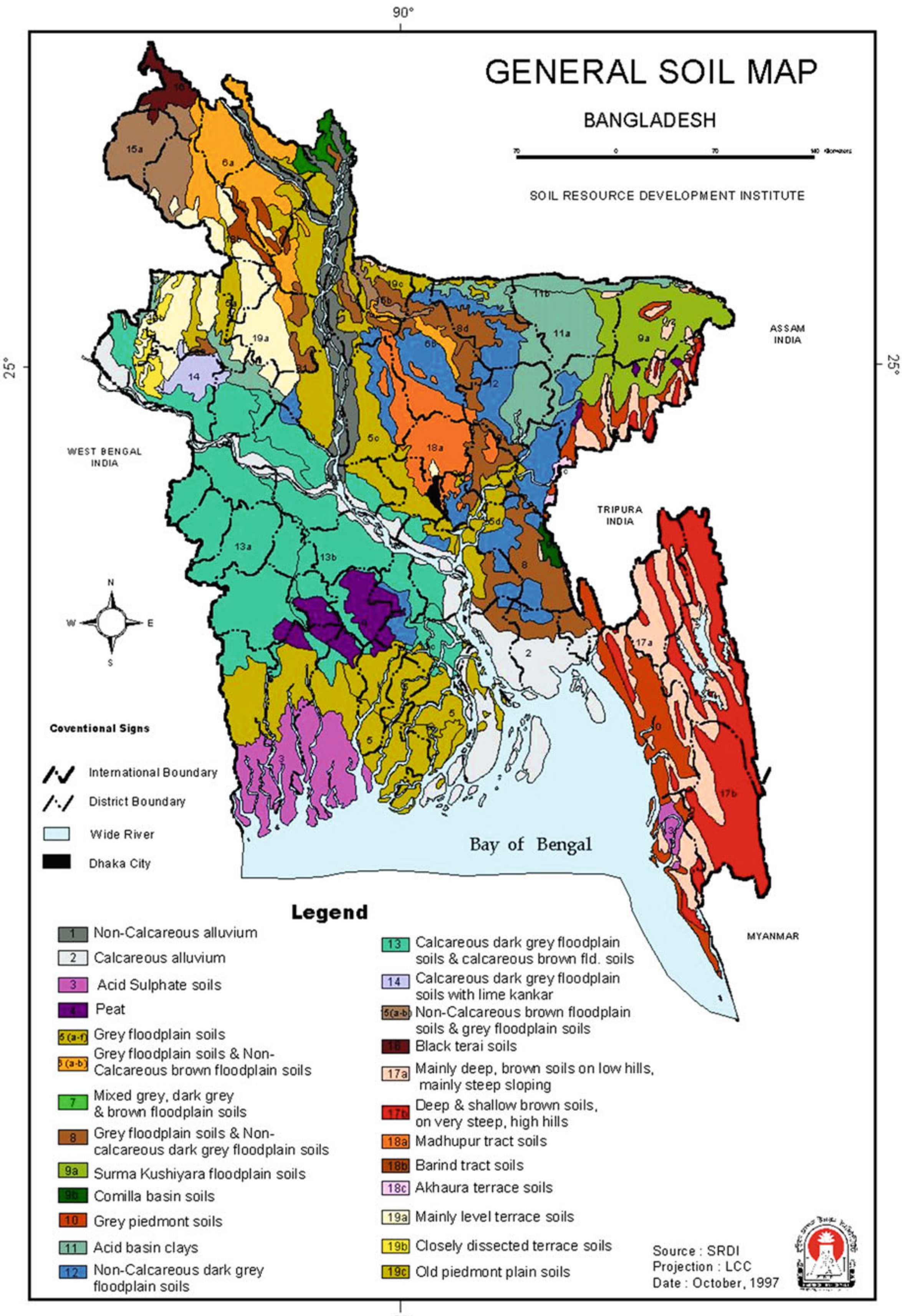

Fig. 2.3 General soil of Bangladesh done in 1997 (*Source* SRDI)

determine their physicochemical properties. All these data thus generated concerning land quality and soil characteristics have been converted to digital format using GIS (Geographic Information System) technology (Imamul Huq and Hoque 2012). The *Land and Soil Resources Utilization Guide* is popularly known as *Upazila Nirdeshika*. This guide has been used for land-use planning, crop-specific fertilizer recommendation, and postdisaster agricultural management.

From 1974 to 1990, SRDI carried out a detailed survey of some experimental farms to generate specific information on soil properties for planning small area-development programs and the location of specific activities. Publication scales for the detailed soil surveys ranged from about 1:5,000–1:10,000. As these surveys were project bound, the use of the information thus generated was limited to the project purposes only (Islam 2003).

It was mentioned earlier that agricultural research laboratories were set up around 1905 in this part of the continent, initiating soil research to improve agricultural production. The earliest records indicate that the investigation into soil fertility on the effect of bone meal and cowdung on Aus rice was initiated in the year 1911 at the farm established in Dhaka. The experiment was popularly known as Birt's experiment and it continued until 1923. The outcome of the experiment indicated substantial yield increases over control. Later, another experiment with bone meal, lime, and green manuring alone and in combination on Aus rice was carried out during 1914–1918 and was known as Basu's experiment. The results of these experiments were not properly analyzed, interpreted, and compiled and thus remained unpublished.

Early investigations into soil fertility from 1931 to 1946 were mostly conducted at the Dhaka farm on Aus and Aman rice with lime, bone meal, rock phosphate, kossiphos, niciphos, diamophos, ammonium sulphate, sulphur, and muriate of potash as well as with bulky organic manures such as green manures, town compost, cow dung, oil cakes, fish manures, bone meal, and so on. The planning and layouts of the experiments were very simple without sufficient replications. However, these experiments provided some very fundamental information on the response of Aus and Aman paddies to soil amendments. These early experiments were extended to different soils of the country with complete soil analyses. More than 400 soil samples were analyzed that provided baseline data for nutrients including N, P, K, Ca, and organic matter. Accordingly, it was made known at the time that the soils of Madhupur Tract were deficient in N,P,K, and lime; Barind Tract soils were deficient in N, P, and lime; and the soils of the Gangetic alluvium were sufficient in K, lime, and organic matter but deficient in N and P.

Between 1953–1954 and 1960–1961, a large number of experiments were conducted to study the comparative efficiencies of different commercial fertilizers, particularly nitrogenous and phosphatic fertilizers on Aus and Aman paddies and winter vegetables. During these periods a series of more complex experiments was performed for balanced nutrient management for paddy, wheat, sugarcane, and vegetables with different combinations of N, P, and K fertilizers as well as combinations of organic and inorganic fertilizers. These experiments were the basis for formulations of different recommendations for these crops. These recommendations were considered unrealistic considering the heterogeneity of the soils. To make the recommendations more realistic, a scheme entitled "Rapid Soil Fertility Survey and Popularization of the Use of Fertilizer in East Pakistan" was implemented in 1957 with 50 experimental centers all over the country. This was later modified and expanded under the name of "East Pakistan Soil Fertility and Soil Testing Institute" in 1963 with 200 experimental centers. The field trials were carried out on farmers' field all over the country and recommendations were made on the basis of the seven soil tracts. This practice continued till 1960. When the soils of Bangladesh were later classified into 17 general soil types, it was felt necessary that fertilizer recommendations be made for these general soil types. As a result, as many as 7,105 field trials on different general soil types of Bangladesh were carried out between 1970 and 1974.

With the introduction of HYV or modern varieties of crops as well as introduction of the Boro season of rice cultivation, the field trials were extended to further microlevels. The first fertilizer recommendation guide was published in 1979 by BARC largely on the basis of soil series information and the results of fertilizer trials. Coordinated soil test crop response correlation studies were conducted from 1980 to 1984 by the Bangladesh Institute of Nuclear Agriculture (BINA), Dhaka University (DU), Bangladesh Jute Research Institute (BJRI), Bangladesh Agricultural Research Institute (BARI), Bangladesh Rice Research Institute (BRRI), and Bangladesh Agricultural University (BAU). Based on the recommendations of these soil test and crop response studies, in 1985 BARC updated the 1979 fertilizer recommendation guide. The concept of soil testing and yield goals for making fertilizer recommendations was introduced for the first time in Bangladesh. The guide was called *Fertilizer Recommendation Guide for Most Bangladesh Crops*, and as such, considered only a few major crops. Over the years, however, there has been a sharp rise in the use of chemical fertilizers although at the time, fertilizer use efficiency at the farm level was very low. The experts concerned thought it pertinent to update the then-current practices for fertilizer use for different crops

grown in the varied range of environment. Moreover, considerable progress was made on soil fertility research. All the data generated by different national research institutes of the country were collected by BARC and a new revised fertilizer recommendation guide was published in 1989 that included some major features such as (a) the diversity of agroecological regions, (b) major cropping patterns, (c) soil fertility levels, and (d) the resource base of farmers and yield goals. The 1989 guide was further updated in 1997. From 1997 to 2005 considerable progress was made on soil fertility and fertilizer management research and extension by the National Agricultural Research System (NARS) Institutes and the extension department. The 1997 guide was further updated in 2005 to include information on more crops and cropping patterns, updated soil nutrient status of different agroecological zones, nutrient balance status, soil and fertilizer management based on the IPNS concept, fertilizer management in multiple cropping systems, minimum tillage, hill farming, and information on the quality control aspects of fertilizer. This 2005 FRG is again being updated for publication in 2012.

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3 Climate

The climate of Bangladesh is characterized by subtropical monsoons. Bangladesh lies between 20°25′ N and 26°38′ N latitude and between 88°01′ E to 92°40′ E longitude. Bangladesh is the largest delta in the world. This delta is formed by the confluence of the Ganges (local name Padma), Brahmaputra (Jamuna), and Meghna Rivers and their respective tributaries. The Ganges unites with the Jamuna (main channel of the Brahmaputra) and later joins the Meghna to empty eventually into the Bay of Bengal. The total land area of Bangladesh is estimated to be 147,570 km^2.

Three seasons are generally recognized:

i. A hot humid summer from March to June; tropical cyclones are most frequent during this period. Temperature and evaporation rates are high.
ii. A moderate, rainy monsoon season from June to October; this is the period of highest rainfall. About 80 % of the total rainfall in Bangladesh occurs during this period.
iii. A cool dry winter from October to March; this is the period of occasional rainfall. The occurrence is uncertain and amounts received are small. During this period the weather is relatively cool, dry, and sunny. However, recently a shift from the above generalization has been recognized.

3.1 Climatic Elements

3.1.1 Temperature

Bangladesh is characterized by wide seasonal variations in rainfall, high temperatures, and high humidity. The mean annual temperature of Bangladesh is 25 °C. In general, maximum summer temperatures range between 32 and 38 °C. April is the warmest month in most parts of the country. January is the coldest month. Ground frost is occasionally experienced in exposed hill areas, but not on the plains. Figure 3.1 gives a graphical view of the maximum, minimum, and average temperature over the year. Figure 3.2 depicts the thermal zones of the country.

3.1.2 Rainfall

Heavy rainfall is characteristic of Bangladesh and varies from 1,700 to 5,500 mm with an average of 1,875 mm. Rajshahi, the northwestern part of Bangladesh, receives the lowest average precipitation and because of its location just south of the foothills of the Himalayas, where monsoon winds turn west and northwest, the region of Sylhet in northeastern Bangladesh receives the greatest average precipitation. The average precipitation in depth (mm per year) in Bangladesh was 2,666 in 2009, according to a World Bank report published in 2010. Average precipitation is the long-term average in depth (over space and time) of annual precipitation in the country (www.tradingeconomics.com/bangladesh/average-precipitation-in-dep).

About 85–90 % of the annual rainfall occurs between mid-April and the end of September. There has been a change in this pattern although the total amount of annual precipitation has not shown any significant variation. The total amount varies from year to year due to the variation in premonsoon rainfall and the irregular incidence of heavy rainfall within the monsoon season. In winter, rainfall may be either from local thunderstorms or from depressions crossing northern India. Figure 3.3 shows the mean annual rainfall pattern of the country and Fig. 3.4 shows the mean monthly rainfall histogram for the country. The mean daily rainfall in different months of the year at various locations of Bangladesh is shown in Fig. 3.5.

3.1.3 Wind

Winds are mostly from the north and northwest in the winter, blowing gently at 1–3 km per hour (0.6–1.9 mph) in the northern and central areas and 3–6 km per hour (1.9–3.7 mph) near the coast. From March to May, violent

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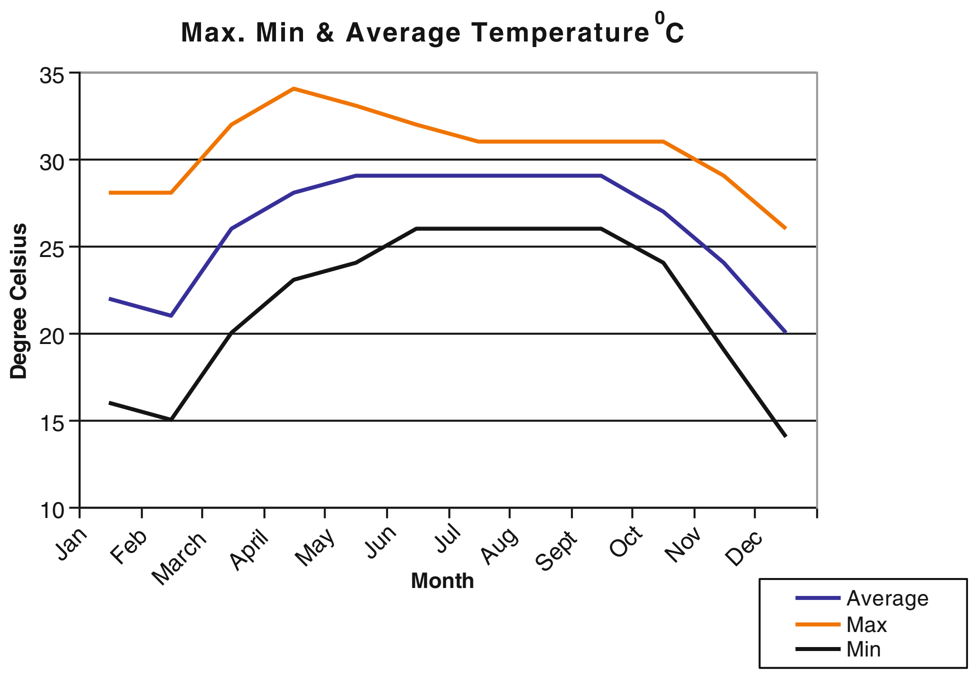


Fig. 3.1 Bangladesh mean, maximum, and minimum temperature (*Source* http://www.dhaka.climatemps.com/)

thunderstorms, called *norwesters* (in the local term: *Kalboishakhi*) by the local English speakers, produce winds of up to 60 km per hour (37.3 mph). During the intense storms of the early summer and late monsoon season, southerly winds of more than 160 km per hour (99.4 mph) cause waves to crest as high as 6 m (19.7 ft) in the Bay of Bengal, which brings disastrous flooding to coastal areas.

3.2 Agroecological Zone (AEZ)

Climate has been one of the key elements in delineating the Bangladesh soils for better crop production. The country has thus been differentiated into as many as 30 agroecological zones, each with its unique characteristic *vis-à-vis* the local agriculture. As such, it became pertinent to the authors that brief descriptions of the various agroecological zones be included in this chapter.

An agroecological zone indicates an area characterized by homogeneous agricultural and ecological characteristics. This homogeneity is more prominent in the subregion and unit levels. The agroecological zones of Bangladesh have been identified on the basis of four elements: physiography, soils, land levels in relation to flooding, and agroclimatology. These 30 zones have been subdivided into 88 agroecological subregions, which have been further subdivided into 535 agroecological units.

AEZ can be regarded as a set of core applications leading to an assessment of land suitability and potential productivity, and a further set of advanced or peripheral applications that can be built on the inventories and results of the core AEZ studies. Outputs of core applications include maps showing agroecological zones and land suitability, and quantitative estimates on potential crop areas, yields, and production. Such information provides the basis for advanced applications such as land degradation assessment, livestock productivity modeling, population support capacity assessment, and land-use optimization modeling.

Physiography forms the primary element in defining and delineating the agroecological regions in Bangladesh. Soils form the second element in defining and differentiating agroecological zones inasmuch as soil conditions determine important properties for plant growth, moisture supply, root aeration, and nutrient supply. The third factor is the land level in relation to flooding. In this regard the country has been classified into five types of land levels such as *highland* (land above normal flood level), *medium highland* (land normally flooded up to about 90 cm deep during the flood season), *medium lowland* (land normally flooded up to between 90 and 180 cm deep during the flood season), *lowland* (land normally flooded up to between 180 and 300 cm deep during the flood season), and *very lowland* (land normally flooded deeper than 300 cm during the flood season). An additional class, *bottomland*, is recognized for depression sites in any land-level class that remains wet throughout the year. The fourth element considered in identifying agroecological zones in Bangladesh comprises the four climatic zones of the country. The combined agroclimatic zones could be superimposed on the zones and subregions to create unique agroecological units.

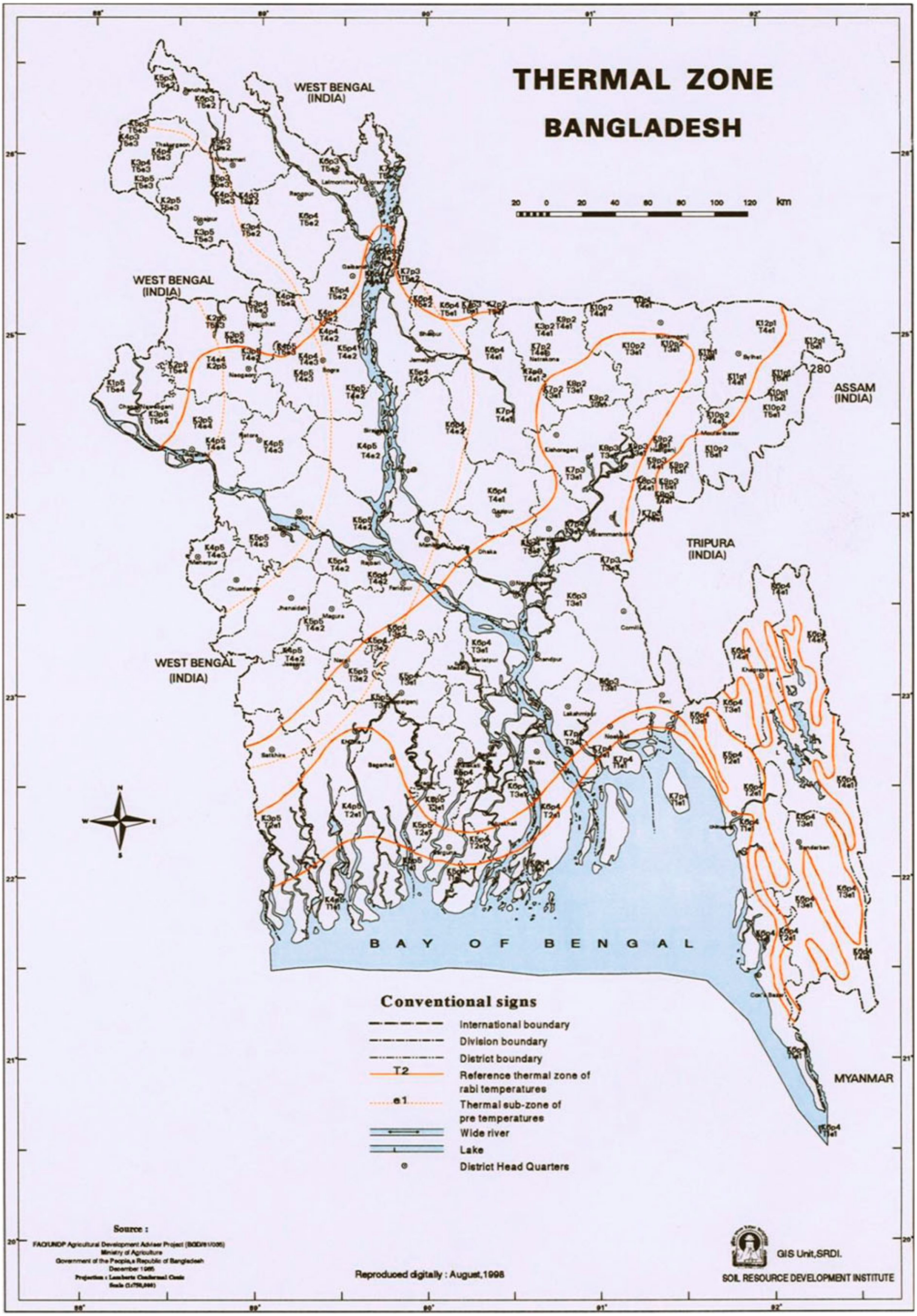


Fig. 3.2 The thermal zones of Bangladesh (*Source* SRDI)

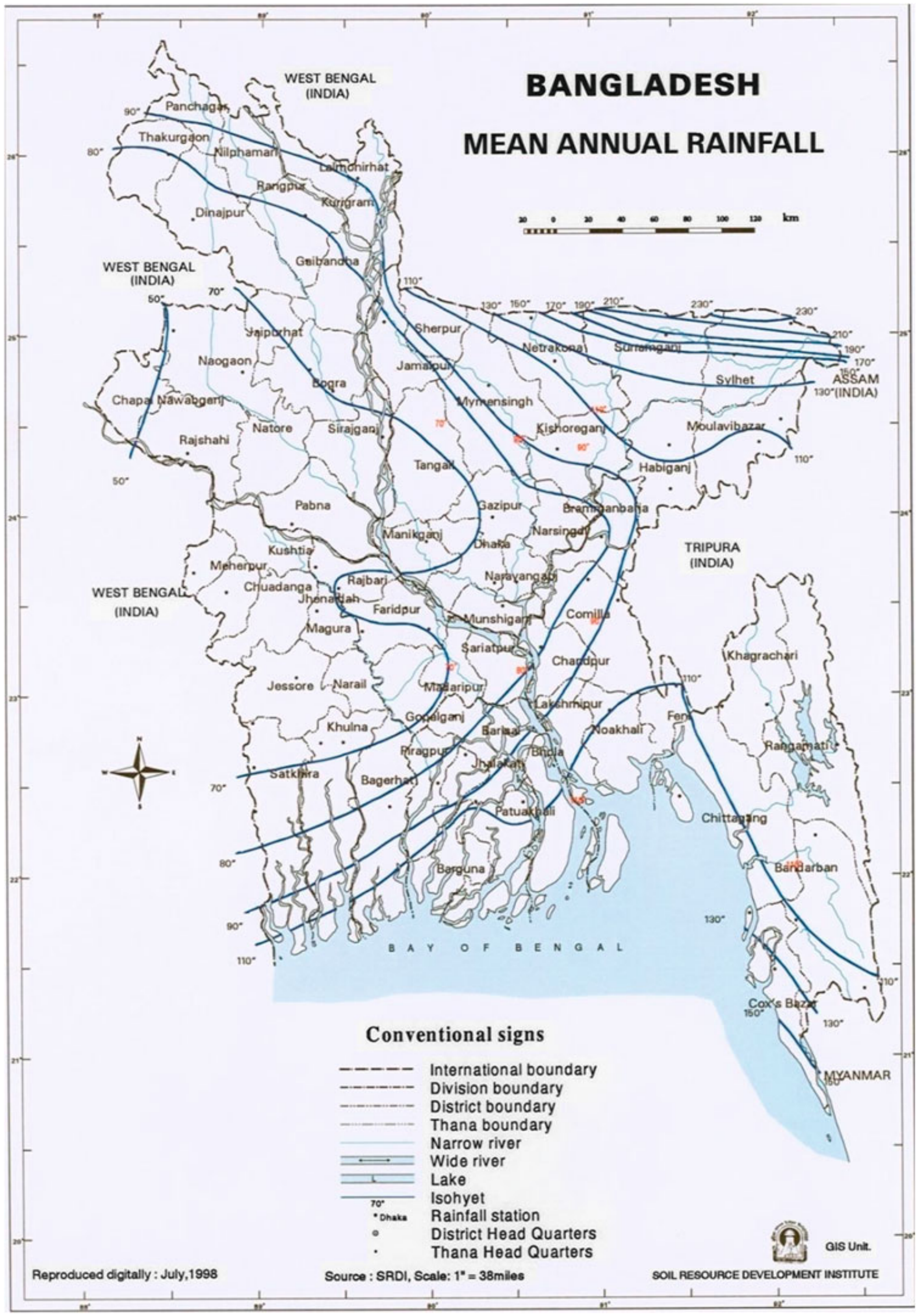


Fig. 3.3 Mean annual rainfall pattern of Bangladesh (*Source* SRDI)

The agroecological zones (AEZ) database is unique and is being extensively used for national and local level production planning purposes. The agroecological resources are increasingly playing an important role in agricultural planning, technology transfer, and specific biophysical resource utilization program activities. The database on AEZ, however, needs updating as over time there have been some changes in the land types because of roads and other structural measures, variability in precipitation and temperature, as well as innovation of modern crop cultivation

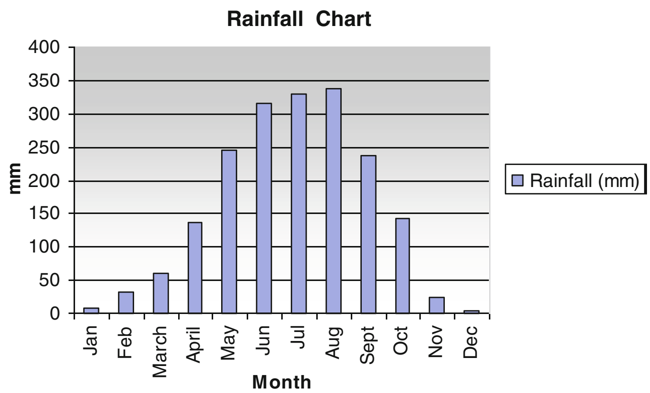


Fig. 3.4 Mean monthly rainfall of Bangladesh (*Source* http://www.dhaka.climatemps.com/)

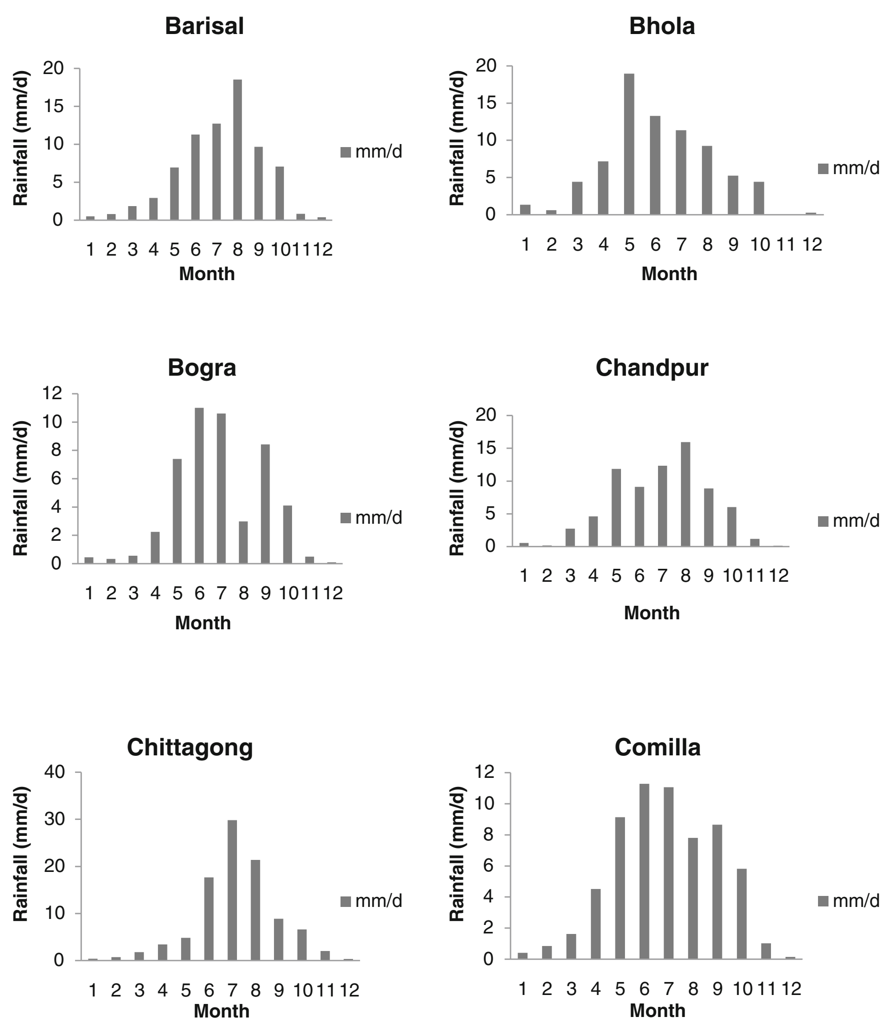
that could survive under different environmental stress conditions. A brief description of 30 AEZ regions and subregions and the soils therein is summarized in Table 3.1 and shown in Fig. 3.6.

3.3 Old Himalayan Piedmont Plain

This distinctive region is developed in an old Tista alluvial fan extending from the foot of the Himalayas. Most of the Panchagarh and Thakurgaon districts and the northwestern part of the Dinajpur district are included in this zone. It covers an area of 4,008 km^2, and has a complex relief pattern.

Deep, rapidly permeable sandy loams and sandy clay loams are predominant in this region. Sands occur locally on ridge tops, and clays occupy a few basin centers. Soil patterns often are complex due to differences in subsoil texture, depth to a sandy stratum, thickness of the dark-colored topsoil, and drainage. They are strongly acidic in topsoil and moderately acidic in subsoil, as well as low in weatherable K minerals. Seven general soil types occur in the region, of which noncalcareous brown floodplain soils, black Terai soils, noncalcareous dark grey floodplain soils, and noncalcareous grey floodplain soils predominate. Organic matter contents are generally higher than in most floodplain soils of Bangladesh. The natural fertility of the soil is moderate but well sustained.

Fig. 3.5 Mean daily rainfall histograms of various locations in Bangladesh on a monthly basis (*Source* 203.208.166.84/mnislam/forecast-rf.htm)



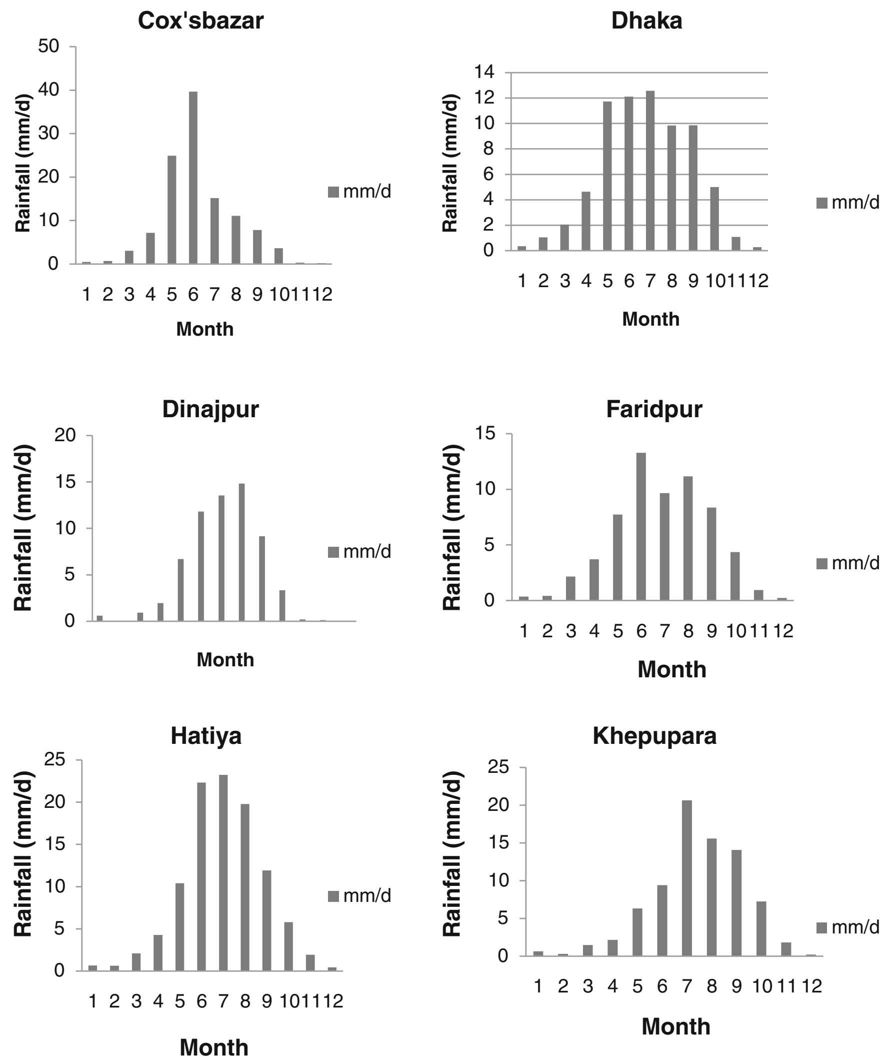


Fig. 3.5 continued

3.4 Active Tista Floodplain

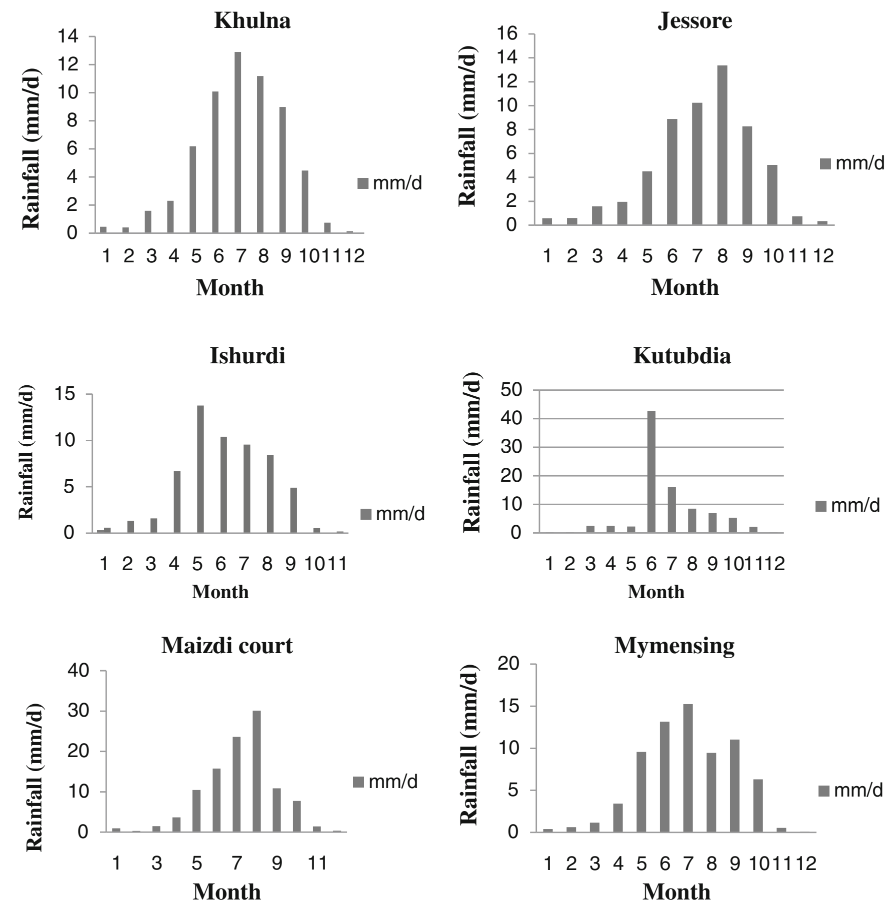
This region includes the active floodplains of the Tista, Dharla, and Dudhkumar Rivers in Nilphamari, Rangpur, Lalmonirhat, Kurigram, and Gaibandha Districts. It covers an area of 830 km^2 and has complex patterns of low, generally smooth ridges, interridge depressions, river channels, and cut-off channels. Most areas are shallowly flooded in the rainy season; flooding is occasionally deep during flood peaks.

The area has irregular patterns of grey stratified sands and silts with some developed grey, silty soils near the boundaries with the Tista meander floodplain. The proportions of sandy and silty alluvium on char land vary from year to year. On average, sandy and silty deposits are roughly equal on the active Tista and Dharla floodplains, whereas sand predominates on the active Dudhkumar floodplain. They are near neutral in reaction and the parent alluvium is rich in weatherable minerals. The organic matter content is low. Four general soil types occur in the region, and of them, noncalcareous alluvium predominates (62 %). Organic matter content and soil fertility level are low to medium.

3.5 Tista Meander Floodplain

This region occupies the major part of the Tista floodplain as well as the floodplain of the Atrai, Little Jamuna, Karatoya, Dharla, and Dudhkumar Rivers. This region extends over 9,468 km^2 covering most of the greater Rangpur, eastern part of Panchagarh and Dinajpur, northern Bogra, and parts of the Jaipurhat, Naogaon, and Rajshahi districts. Most areas have broad floodplain ridges and almost level basins. The higher parts of the floodplain ridges stand above normal flood level, but the soils may periodically become wet during periods of heavy monsoon rainfall. Lower parts

Fig. 3.5 continued



of the ridges and basins are mainly shallowly flooded in the rainy season. There is an overall pattern of olive brown, rapidly permeable, loamy soils on the floodplain ridges, and grey or dark grey, slowly permeable, heavy silt loam or silty clay loam soils on the lower land. Clay soils occupy small areas in basins in subregions of Rangpur, Nilphamari, Kurigram, Bogra, Dinajpur, and Rajshahi. The parent materials are medium weatherable K minerals. Soils have very high moisture-holding capacity, slightly acidic to very strongly acidic in reaction, and low in organic matter content on the higher land, but moderate in the lower parts. Fertility level is low to medium.

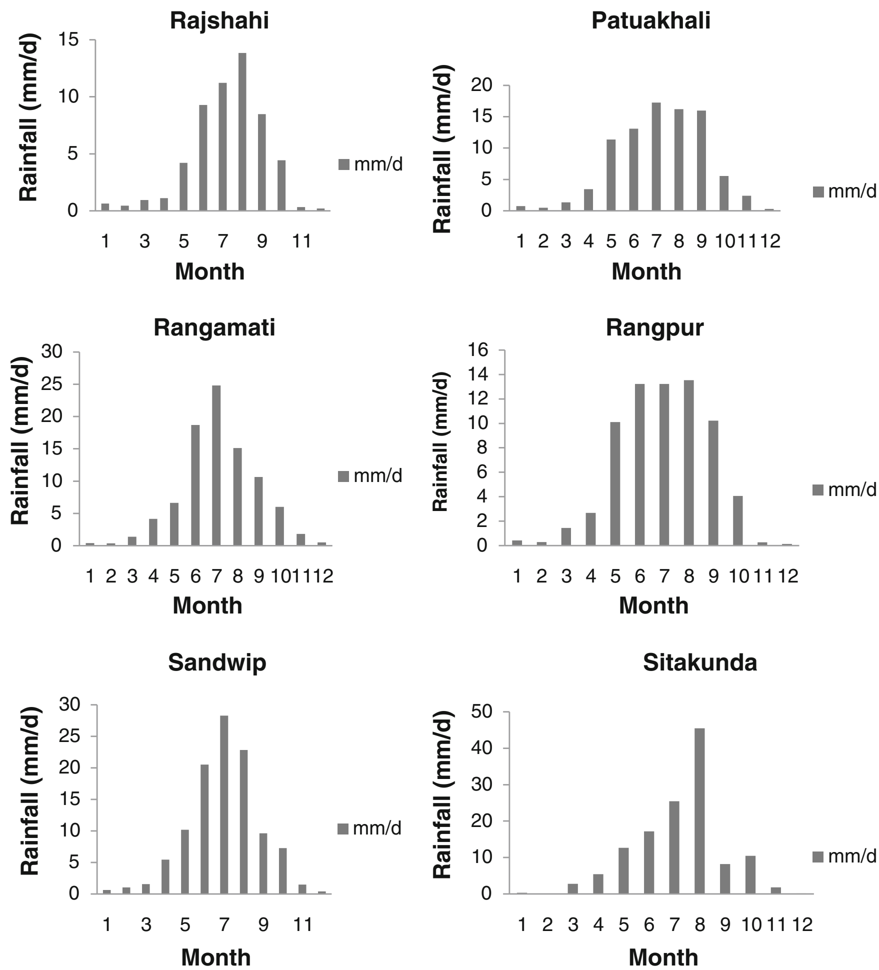
3.6 Karatoya–Bangali Floodplain

This region is very similar to the Tista meander floodplain in physiography and soil. Karatoya–Bangali alluvium apparently comprises a mixture of Tista and Brahmaputra sediments. The eastern half of Bogra and most of the Sirajganj districts are included in this zone that covers an area of 2,577 km^2. Most areas have smooth, broad, floodplain ridges and almost level basins. Seasonal flooding is mainly shallow in floodplain basins in Bogra and Pabna, and upper parts of the ridges stand above normal flood levels. Basins in Pabna are moderately deeply or deeply flooded and ridges are shallowly flooded.

The soils are grey silt loams and silty clay loams on ridges and grey or dark grey clays in basins. The highest ridge soils are rapidly permeable and have a low moisture-holding capacity. Most other soils have slow permeability, especially those puddled for transplanted aman cultivation, and they have high moisture-holding capacity. Five general soil types occur in the region, of which noncalcareous grey floodplain and noncalcareous dark grey floodplain soils predominate.

Topsoil reaction varies from slightly to very strongly acidic. Subsoils are mainly slightly acidic to slightly alkaline, but the upper part of the subsoil in the basins often is

Fig. 3.5 continued



medium acidic and some heavy basin clays have strongly acidic subsoils. Organic matter contents are generally low (<1.5 %) in the cultivated layer of ridge soils and moderate (up to 2.5 %) in basin soils.

3.7 Lower Atrai Basin

This region comprises the low-lying areas between the Barind Tract and the Ganges River floodplain. It includes the Chalan beel area. This region covers 851 km^2. Most of the region lies in the Naogaon and Natore districts. Small areas extend into the Rajshahi, Bogra, and Sirajganj districts. Smooth, low-lying basin land occupies most of the region. Unembanked areas are deeply and often rapidly flooded by heavy local rainfall. Basins drain slowly after the rainy season, and basin centers remain naturally wet for most or all of the dry season.

Dark grey, heavy, acidic clays predominate in this smooth low-lying basin land. Near the southern boundary, small areas of calcareous soils of the Ganges River floodplain occur, and there are small areas of loamy, noncalcareous ridge soils of the Middle Atrai and Little Jamuna floodplains near the boundaries with those units. Seven general soil types occur in the region. Organic matter contents range about 1.5 % on the higher ridges and 2.5–5 % in basin centers. Permeability is generally slow, but may be rapid for a period in the Kharif season in basin clays that crack widely and deeply during dry season. Natural water-holding capacity is low in the heavy clays, but many soils stay wet or moist for part of the dry season. The status of essential nutrients is medium, whereas the

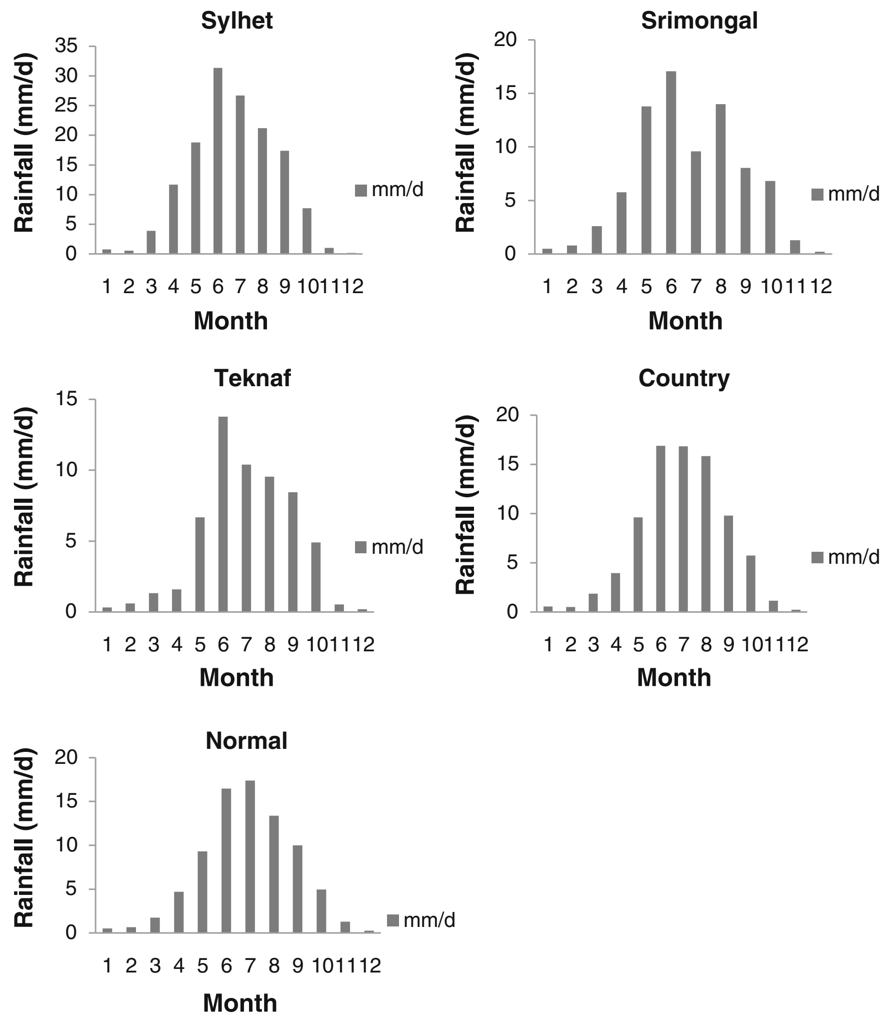


Fig. 3.5 continued

level of available K (potassium) is high. The fertility status of soils is moderate.

3.8 Lower Punarbhaba Floodplain

This small region occupies basins and beels (large water bodies) separated by low floodplain ridges. This region includes western parts of the Naogaon and northern part of Chapai Nawabganj districts covering 129 km^2. Most of the region is moderately deeply or deeply flooded in the rainy season. Basin centers are subject to rapid, sometimes early, flooding by runoff from the adjoining high Barind Tract or flash floods coming down the Punarbhaba River, and they stay wet for part or all of the dry season. Dark grey, mottled red, very strongly acidic, heavy clays occupy both ridge and basin sites in this area. About 70 % of the area is occupied by acidic basin clays that comprise dark grey, heavy clays that crack widely in dry season. The general fertility level is medium, and the organic matter content is 2–5 % in the cultivated layer and 1–2 % in the subsoil. Permeability is probably very slow in soils that remain wet naturally or with irrigation, but may be rapid in the dry season.

3.9 Active Brahmaputra–Jamuna Floodplain

This region comprises the belt of unstable alluvial land along the Brahmaputra–Jamuna Rivers where land is constantly being formed and eroded by shifting river channels. It has an irregular relief of broad and narrow ridges and depressions, interrupted by cutoff channels and active channels. Both the outline and relief of char formations are liable to change each flood season due to bank erosion by shifting channels and to deposition of irregular thickness.

Table 3.1 Agroecological zones of Bangladesh (FAO-UNDP 1988)

ID	Zones/Regions	Sub regions
1	Old Himalayan Piedmont Plain	1a. North-central; 1b. Northern; 1c. Southern
2	Active Tista Floodplain	Active Tista Floodplain
3	Tista Meander Floodplain	3a. Central; 3b. Eastern; 3c. Lower Atrai Floodplain; 3d. Lower Little Jamuna Floodplain; 3e. Northeastern and Southern Northwestern; 3f. Upper Little Jamuna and Middle Atrai Floodplain
4	Karatoya–Bangali Floodplain	4a. Northern and Central; 4b. Southwestern
5	Lower Atrai Basin	Lower Atrai Basin
6	Lower Punarbhaba Floodplain	Lower Punarbhaba Floodplain
7	Active Brahmaputra–Jamuna Floodplain	Active Brahmaputra–Jamuna Floodplain
8	Young Brahmaputra and Jamuna Floodplain	8a. High Jamuna Floodplain; 8b. Upper Brahmaputra Floodplain; 8c. Upper Brahmaputra–Jamuna Floodplain
9	Old Brahmaputra Floodplain	9a. Bansi Valley; 9b. High; 9c. Low; 9d. Medium High; 9e. Medium Low
10	Active Ganges Floodplain	Active Ganges Floodplain
11	High Ganges River Floodplain	11a. Central and Southern; 11b. Ganges–Mahananda Floodplain; 11c. Northern
12	Lower Ganges River Floodplain	12a. Central; 12b. Eastern
13	Ganges Tidal Floodplain	13a. Khulna Sundarbans; 13b. Nonsaline, calcareous; 13c. Nonsaline, calcareous and non-calcareous; 13d. Nonsaline, noncalcareous 13e. Saline, Acid Sulphate Soils; 13f. Saline, calcareous and noncalcareous; 13g. Saline, noncalcareous
14	Gopalganj–Khulna Beels	Beel centers
15	Arial Beel	Arial Beel
16	Middle Meghna River Floodplain	Middle Meghna River Floodplain
17	Lower Meghna River Floodplain	17a. Calcareous, flood protected; 17b. Calcareous, unembanked; 17c. Noncalcareous, flood protected; 17d. Noncalcareous, unembanked
18	Young Meghna Estuarine Floodplain	18a. Nonsaline: Central Bhola; 18b. Nonsaline: Meghna Estuary Charland; 18c. Nonsaline: North Bhola; 18d. Saline: Central Bhola; 18e. Saline: Noakhali, Hatiya and Meghna Estuary; 18f. Saline: Sandwip and South Bhola
19	Old Meghna Estuarine Floodplain	19a. Dhaka–Narayanganj–Demra Project Area; 19b. High: Old Meghna Estuarine Floodplain; 19c. Low: Daudkandi–Habiganj; 19d. Low: Dhaka–Shariatpur–Barisal; 19e. Low: Eastern Kishoreganj; 19f. Low: Gopalganj Beels margins 19g. Low: Habiganj–North Brahmanbaria; 19h. Low: Titas Floodplain; 19i. Medium Low; 19j. Very poorly drained: Laksham–Begumganj
20	Eastern Surma–Kushiyara Floodplain	Eastern Surma–Kushiyara Floodplain
21	Sylhet Basin	21a. Central and Southern; 21b. Northern; 21c. Western
22	Northern and Eastern Piedmont Plain	22a. Northern and Eastern Basins; 22b. Northern and Eastern Plains and Basins; 22c. Northwestern Plains and Basins; 22d. South Sylhet Piedmont Plains
23	Chittagong Coastal Plain	23a. Beach Ridges, Mangrove Swamp and Mud Clay; 23b. Mangrove Tidal Floodplain; 23c. Piedmont Plains and River Floodplains; 23d. Young Tidal Floodplain
24	St. Martin's Coral Island	St. Martin's Coral Island
25	Level Barind Tract	25a. Highland and Medium Highland; 25b. Medium Lowland and Lowland
26	High Barind Tract	High Barind Tract
27	Northeastern Barind Tract	27a. Mainly poorly drained; 27b. Mainly well drained; 27c. Mixed well drained and poorly drained
28	Madhupur Tract	28a. Mainly poorly drained level terrace; 28b. Mainly well drained dissected terrace
29	Northern and Eastern Hills	29a. Low hills and Piedmont Plains; 29b. Mainly high hill ranges; 29c. Mainly low hills
30	Akhaura Terrace	Akhaura Terrace

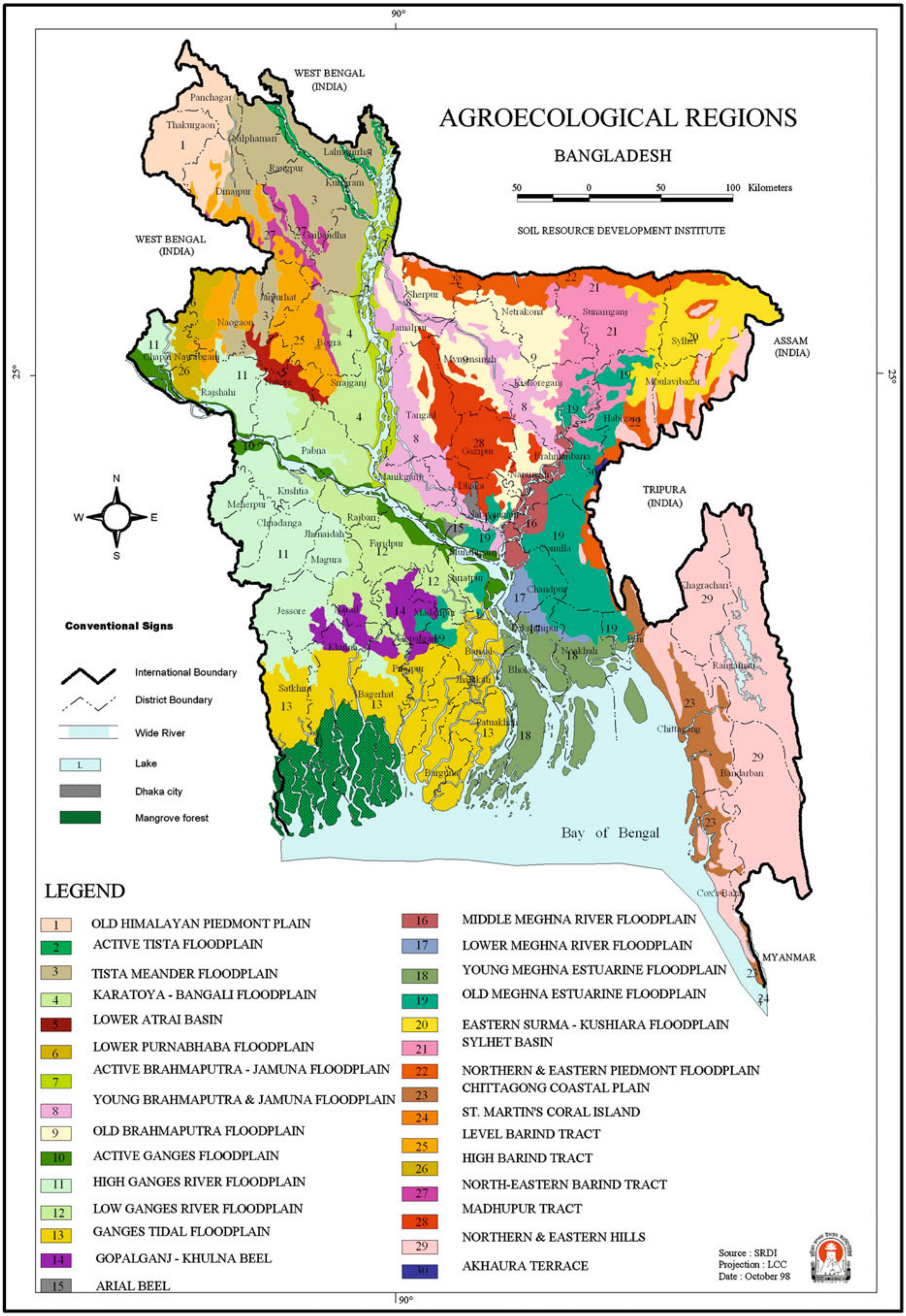


Fig. 3.6 Map showing the agroecological zones (AEZ) of Bangladesh (*Source* SRDI)

Virtually the whole area is subject to seasonal flooding: shallow on higher parts and deep on the lower parts. Depression sites remain wet throughout the year. This region covers eastern parts of Kurigram, Gaibandha, Bogra, Sirajganj, and Pabna districts and western parts of Sherpur, Jamalpur, Tangail, and Manikganj districts. This zone extends over 3,190 km^2. The area is occupied by sandy and silty alluvium, mostly the charlands, but there are some developed grey silty soils on older areas of alluvium. The proportions of sandy and silty alluvium vary from place to place and year to year. The parent alluvium is rich in weatherable minerals, especially biotite, low in organic matter, and neutral to moderately alkaline in reaction. Six general soil types occupy the area. Organic matter status is low and fertility status is low to medium.

3.10 Young Brahmaputra and Jamuna Floodplain

The region comprises the area of Brahmaputra sediments. The landscape and soils closely resemble those of parts of the Tista Meander Floodplain and the Karatoya–Bangali Floodplain. This region includes the western part of the Sherpur, Jamalpur, and Tangail districts; parts of Manikganj, Dhaka, Munshiganj, Narayanganj, and Ghajipur districts; and a belt adjoining the Old Brahmaputra channel through Mymensingh, Kishoreganj, and Narsingdi districts covering an area of 5,924 km^2. It has a complex relief of broad and narrow ridges, interridge depressions, partially in filled cutoff channels and basin. The ridge soils lie above normal flood levels, but they are submerged for one to two weeks in years with exceptionally high floods. The middle and lower parts of ridges are mainly subject to shallow flooding, whereas basins are subject to moderate to deep flooding. This area is occupied by permeable silt loam to silty clay loam soils on the ridges and impermeable clays in the basins. Brahmaputra alluvium is rich in weatherable minerals, especially biotite. Most of the soils have stratified alluvium above 50 cm. Silt loams and silty clay loams occupy the greater part of the region. The organic matter in the cultivated layer ranges from around 1 % on the ridges to around 2 % in most depressions and basins. The soils are neutral to slightly acidic in reaction. The highest ridge soils are permeable. Lower soils are moderately permeable, but basins are slowly permeable.

3.11 Old Brahmaputra Floodplain

This region occupies a large area of Brahmaputra sediments before the river shifted to its present Jamuna channel about 200 years ago. Large areas in Sherpur, Jamalpur, Tangail, Mymensingh, Netrakona, Kishoreganj, Narsingdi, and small areas in the east of the Dhaka and Gajipur districts are included in this region. It covers an area of 7,230 km^2. Most areas have broad ridges and basins. Relief is irregular, especially near the old and present river channels. The highest ridges are moderately well drained. Depressions and basins are moderately deeply flooded to deeply flooded. Dark grey floodplain soils generally predominate. Soils of the area are mostly silt loams to silty clay loams on the ridges and clay in the basins. The reaction of the cultivated layer is usually medium to very strongly acidic: higher in permeable ridge soils and lower in basin soils. Moisture-holding capacity is high in deep silt loams on ridges, but low in more sandy or shallow ridge soils. General fertility level is low, and organic matter content is low on the ridges and moderate in the basins.

3.12 Active Ganges Floodplain

This region occupies unstable alluvial land within and adjoining the Ganges River. The region extends to 3,334 km^2 along the Ganges and the lower Meghna River channels from the Indian border in the Chapai Nawabganj, and Rajshahi districts to the mouth of the Meghna estuary in the Laxmipur and Barisal districts. It has an irregular relief of broad and narrow ridges and depressions interrupted by cutoff channels and active channels. Seasonal flooding is shallow on ridges and moderately deep or deep in depressions. The area has complex mixtures of calcareous sandy, silty, and clayey alluvium, with more shallowly developed brown loamy soils on ridges and dark grey clays in depressions on older alluvial areas. Ganges alluvium is rich in weatherable minerals. Soils are low in organic matter and mildly alkaline in reaction. General fertility level is medium. The general soil types predominantly include calcareous alluvium and calcareous brown floodplain soils.

3.12.1 High Ganges River Floodplain

This region includes the western part of the Ganges River floodplain which is predominantly highland and medium highland. This zone covers Chapai Nawabganj, Rajshahi, southern Pabna, Kushtia, Meherpur, Chuadanga, Jhenaida, Magura, Jessore, and northern parts of the Satkhira and Khulna districts, together with minor areas in the Naogaon and Narail districts covering an area of 13,205 km^2. Most areas have a complex relief of broad and narrow ridges and interridge depressions, separated by areas with smooth, broad ridges and basins. The upper parts of high ridges stand above normal flood level. Lower parts of ridges and basin margins are seasonally shallowly flooded. Some

highland soils, mainly in the west, are moderately well drained, but the majority become wet periodically during spells of heavy monsoon rainfall. Basin centers are subject to flash floods from local runoff, and remain wet for part or all of the dry season. There is an overall pattern of olive-brown, silt loams and silty clay loams on the upper parts of the floodplain ridges and dark grey, mottled brown, mainly clay soils on lower ridges and in basins. General soil types predominantly include calcareous dark grey floodplain soils and calcareous brown floodplain soils. Soils are slightly alkaline in reaction. The general fertility level is low. Organic matter content in the brown ridge soils is low (<1.5 %) but higher in the dark grey soils (2–5 %).

3.13 Lower Ganges River Floodplain

This region comprises the eastern half of the Ganges River floodplain which is low-lying. The region includes Natore, Pabna, Goalundo, Faridpur, Madaripur, Gopalganj, and Sariatpur; eastern parts of Kushtia, Magura, and Narail; northeastern parts of Khulna, and Bagerhat; northern Barisal; and southwestern parts of the Manikganj, Dhaka, and Munshiganj districts. The area extends up to 7,968 km^2 and has a typical meander floodplain landscape of broad ridges and basins. In most parts of the region, the highest parts of the ridges stand above normal flood level. However, they become wet during periods of heavy monsoon rainfall when the surrounding land is flooded and they may be submerged for a short period during exceptionally high flood. Basins are moderately deeply or deeply flooded. The general soil pattern is olive-brown silt loams and silty clay loams on the highest parts of the floodplain ridges and dark grey silty clay loam to heavy clays on lower sites. Basin clays are more extensive. General soil types predominantly include calcareous dark grey and calcareous brown floodplain soils. Organic matter content in the cultivated layer ranges from less than about 1.5 % in brown ridges soils to 2.5 % in most dark grey soils and more than 5 % in some basin center soils that stay wet for most or all of the dry season.

3.14 Ganges Tidal Floodplain

This region occupies an extensive area of tidal floodplain land in the southwest of the country that include most parts of Barisal, Jhalakati, Pirojpur, Patuakhali, Barguna, Bagerhat, Khulna, and Satkhira districts. It extends up to 17,066 km^2. The greater part of this region has smooth relief having large areas of salinity. Riverbanks generally stand about a meter or less above the level of adjoining basins. The land is tidally flooded where not embanked. Flooding is mainly shallow, but it is moderately deep in some basin centers. There is a general pattern of grey, slightly calcareous, loamy soils on river banks and grey or dark grey, noncalcareous, heavy silty clays in the extensive basins. Calcareous soils occupy a relatively higher proportion of the landscape. Acidic sulphate soils also occupy a significant part of the area, where it is extremely acidic during the dry season. Most of the topsoils are acidic and subsoils are neutral to mildly alkaline. Soils of the Sundarban areas are alkaline. The general fertility level is high, with medium to high organic matter content.

3.15 Gopalganj–Khulna Beels

This region occupies extensive low-lying areas between the Ganges River floodplain and the Ganges tidal floodplain which include a number of separate basin areas in the Madaripur, Gopalganj, Narail, Jessore, Bagerhat, and Khulna districts covering an area of 2,247 km^2. The area is almost level. Low-lying basins occupy most of the region, with low ridges along rivers and creeks. The region is seasonally moderately deeply or deeply flooded. Basin centers remain wet throughout the dry season. Southern parts are flooded tidally mainly by fresh water, but by brackish water near Khulna. Soils of the area are grey, and dark grey, acidic, heavy clays overlay peat or muck at 25–100 cm. Soft peat and muck occupy perennially wet basin centers. Calcareous brown and dark grey loam to clays occupy a generally narrow strip on river banks, but creeks in peat areas do not have mineral soils on their banks. The basin soils stay wet for most or all of the dry season. General soil types include mainly peat and noncalcareous dark grey floodplain soils. The organic matter content is medium to high and the fertility level is medium.

3.15.1 Arial Beel

This region occupies a low-lying basin between the Ganges and Dhaleswari Rivers in the south of the former Greater Dhaka district. It has much in common with the Lower Atrai basin and the Gopalganj–Khulna beels. This region includes the Munshiganj and Dhaka districts covering an area of 144 km^2. Relief is locally irregular near *khals* (natural or man-made river channels) and where raised cultivated platforms have been made. The area is subject to being deeply flooded in the rainy season. The soils of this area are dark grey, acidic heavy clays. Grey and dark grey soils of the Young Brahmaputra and Old Meghna Floodplains probably occur locally near the eastern boundary. Noncalcareous dark grey floodplain soil is the chief general

soil type (app. 70 %). Organic matter content generally exceeds 2 % in the top subsoil. Available moisture-holding capacity is inherently low. The general fertility level is medium to high.

3.16 Middle Meghna River Floodplain

This region occupies an abandoned channel of the Brahmaputra River on the border between the Greater Dhaka and Comilla districts. This region covers an area of 1,555 km^2. The region includes areas of old Brahmaputra *chars* (naturally accreted land masses in rivers) within the Meghna River as well as adjoining parts of the mainland. It comprises various kinds of relief. Most of the soils are seasonally deeply flooded, except on high floodplain ridges. Soils of the area are grey loam on the ridges and grey to dark grey clays in the basins. The dominant general soil type is noncalcareous grey floodplain soil. Cultivated topsoils are generally strongly acidic and subsoils are slightly acidic to slightly alkaline. Organic matter content is low and the general fertility level is medium with low N and organic matter.

3.17 Lower Meghna River Floodplain

This area occupies the transitional area between the Middle Meghna River Floodplain and the Young Meghna Estuarine Floodplain. This region includes the Chandpur, Laxmipur, and Noakhali districts covering an area of 909 km^2. The region has slightly irregular relief. The banks of the river are constantly eroding. The land is mainly moderately deeply flooded. Soils of this area are relatively uniform: silt loams occupy relatively higher areas and silty clay loams occupy the depressions. Five general soil types occur in the region. Noncalcareous dark grey floodplain and calcareous grey floodplain soils are major components of general soil types. Top soils are moderately acidic and subsoils neutral in reaction. The general fertility level is medium to high with low to medium organic matter content.

3.18 Young Meghna Estuarine Floodplain

This region occupies young alluvial land in and adjoining the Meghna estuary. This region extends up to 9,269 km^2 covering parts of the Chittagong, Feni, Noakhali, Bhola, Barisal, Patuakhali, and Barguna districts. The area is almost level with very low ridges and broad depressions. Shifting channels constantly erode land and deposit new char formations. The land is mainly seasonally shallowly flooded by rainwater. Flooding is mainly by fresh water, except in the extreme south and in marginal areas that are tidally flooded. The major soils are grey to olive, deep, silt loams stratified either throughout or at a shallow depth. Young soils are calcareous throughout and mainly saline in the dry season. Older soils are noncalcareous and are very slightly or not saline. Calcareous alluvium and noncalcareous grey floodplain soils are the dominant general soil types. The general fertility is medium and the organic matter content is low.

3.19 Old Meghna Estuarine Floodplain

This region occupies a large area of mainly low-lying land between the south of the Surma–Kushiyara floodplain and the northern edge of the young Meghna estuarine floodplain. This region extends over the Kishoreganj, Habiganj, Brahmanbaria, Comilla, Chandpur, Feni, Noakhali, Narsingdi, Dhaka, Sariatpur, Madaripur, Gopalganj, and Barisal districts covering an area of 7,740 km^2. The area is smooth, almost level, floodplain ridges and shallow basins. Seasonal flooding ranges from shallow to moderately deep and deep. Soils are relatively uniform within the region, both between adjoining ridges and basins. Most soils have a dark grey to black topsoil. Silt loam soils predominate on highlands and silty clay to clay on lowlands. Organic matter contents in the cultivated layer range from 1 to 2.5 % in most ridges and from 2 to 5 % or more in depression soils. Top soils are moderately acidic, but subsoils are neutral in reaction. The general fertility level is medium. Permeability is mainly moderate in the higher soils and slow in depression soils. Moisture-holding capacity generally is high, except in some loose silty ridge soils and some basin clays.

3.20 Eastern Surma–Kushiyara Floodplain

This region occupies the relatively higher parts of the Surma–Kushiyara floodplain formed on sediments of the rivers draining into the Meghna catchment area from the Northern and Eastern Hills. This region extends over the Sylhet, Moulavi Bazar, Sunamganj, and Habiganj districts that cover an area of 4,622 km^2. The area is mainly smooth broad ridges and basins with 3–6 m differences in elevation. Ridges are mainly shallowly flooded within field *bunds* (raised barrier) when high floods occur. Basins are deeply flooded. The whole area is subject to early floods and rapid rise in water level following heavy rainfall locally and in the adjoining hills. This area is occupied by grey, heavy silty clay loams on the ridges and clays in the basins. Small areas of loamy soils occur alongside rivers, together with mixed sandy and silty alluvium. Peat occupies some wet basin centers. Topsoil reaction is strongly or very strongly acid. Basin soils are medium to very strongly acidic in the upper subsoil, gradually becoming less acidic to neutral

below about 50 cm. The organic matter content of the soil is moderate. Permeability is slow in most soils and the moisture-holding capacity is inherently moderate.

3.21 Sylhet Basin

This region occupies the lower western side of the Surma–Kushiyara floodplain which extends over large parts of the Sunamganj, Habiganj, Netrokona, Kishoreganj, and Brahmanbaria districts covering an area of 4,573 km^2. The land is mainly smooth broad basins with narrow rims of higher land along rivers. Relief is locally irregular near rivers. Ridges are mainly moderately deeply flooded, but they are shallowly flooded along the Surma River in the north. Basins are deeply or very deeply flooded. Soils of the area are grey silty clay loams and clay loam on the higher parts that dry out seasonally and grey clays in the wet basins. The soils have a moderate content of organic matter and soil reaction is mainly acidic. Fertility level is medium to high.

3.22 Northern and Eastern Piedmont Plains

This is a discontinuous region occurring as a narrow strip of land at the foot of the northern and eastern hills, except in the Greater Chittagong district and part of the Feni district. The region extends over the Sherpur, Netrakona, Sunamganj, Sylhet, Moulavi Bazar, Habiganj, Brahmanbaria, and Comilla districts covering 4,038 km^2. The region comprises merging alluvial fans that slope gently outward from the foot of the northern and eastern hills into smooth low-lying basins. Locally, the relief is irregular, close to rivers and streams crossing the region, especially on higher land near the hills. Larger parts are above normal flood level. Lower parts are shallowly to moderately deeply flooded in the rainy season. The region has complex soil patterns due to the irregular deposition of sediments of different textures during successive flash floods. Grey piedmont soils and noncalcareous grey floodplain soils are the major general soil types of the area. The greater part of the area is occupied by soils with sandy loam to silty clay texture. The soil is slightly acidic to strongly acidic in reaction. The general fertility level is low to medium.

3.23 Chittagong Coastal Plain

This region occupies the plain land in the Greater Chittagong district and the eastern part of the Feni district. The region extends up to 3,720 km^2. It is a compound unit of piedmont, river, tidal, and estuarine floodplain landscapes. Piedmont and river floodplain ridges stand above normal flood level, but they are periodically submerged by flash floods. Most other land is shallowly flooded in the rainy season, with moderately deep flooding in some basins. The major problem in these soils is high salinity during the dry season (October to May). Despite the compound nature of this region, soils are relatively uniform over most of the area, with grey, near-neutral, silt loams and silty clay loams. Acidic sulphate soils occur in mangrove tidal floodplains. The general fertility is medium and the organic matter content is low to moderate.

3.24 ST. Martin's Island

This small but distinctive region occupies the whole of St. Martin's Island in the extreme south of the country which extends to 8 km^2. The area has very gently undulating old beach ridges and interridge depressions, surrounded by sandy beaches. The ridges stand above normal tide level. Interridge depressions are shallowly flooded by rainwater or saline tidal water. The soils are developed entirely on old and young coral beach sands. Calcareous alluvium is the only general soil type of the area. The general fertility level is low with poor moisture-holding capacity. Most of the old beach ridge soils support only grasses and shrubs, but coconut and *rabi* (dry season) spices occupy a small area.

3.25 Level Barind Tract

This region is developed over Madhupur clay. It occupies about 80 % of the Barind Tract. This region extends over the Dinajpur, Gaibandha, Jaipurhat, Bogra, Naogaon, Natore, and Sirajganj districts. The area of this region is 1,957 km^2. The landscape is almost level, with 60–90 cm local differences in elevation. The area is seasonally flooded by rainwater. Although the major soils appear to be uniform on the surface there is, however, a considerable variation in the subsoils. The predominant soils have grey, silty, puddled topsoil with plough pan. This layer overlies grey, heavy, little weathered Madhupur clay which often contains many large, hard, lime nodules. Shallow grey terrace soils and deep grey terrace soils are the major components of general soil types of the area. The soils are slightly acidic to acidic in reaction. The available moisture-holding capacity is low, and the organic matter status is very low.

3.26 High Barind Tract

This includes the southwestern part of the Barind Tract where the underlying Madhupur clay had been uplifted and cut into by deep valleys. This tract covers the districts of

Rajshahi, Nawabganj, and Naogaon and extends up to 16 km^2. The soils include puddled silt loam to silty clay loam in the topsoils and porous silt with mottled plastic clay at varying depth. Deep grey terrace soils and grey valley soils are the major components of the general soil types of the area. The general fertility status is low, due to a low status of organic matter.

3.27 Northeastern Barind Tract

This region occupies about 10 % of the Barind Tract in several discontinuous areas on the northeastern margins. This region extends over the Dinajpur, Rangpur, Gaibandha, Jaipurhat, and Bogra districts covering an area of 1,079 km^2. In most soils, the relief is smooth and almost level. Most areas of this region are better drained than the adjoining lands. A few valleys are seasonally deeply flooded and their lower parts remain wet or submerged throughout the dry season. The Madhupur clay underlying this region is deeply weathered. It has silty or loamy topsoil and clay loams to clay subsoil. The soils are strongly acidic in reaction. The organic matter in the soils is low, and general fertility is poor.

3.28 Madhupur Tract

This is a region of complex relief and soils developed over the Madhupur clay. It extends over the Dhaka, Ghazipur, Narsingdi, Narayanganj, Tangail, Jamalpur, Mymensingh, and Kishoreganj districts that cover an area of 4,244 km^2. The landscape comprises level upland, closely or broadly dissected terraces associated with either shallow or broad deep valleys. Eleven general soil types exist in the area of which deep red brown terrace, shallow red brown terrace soils, and acidic basin clays are the major ones. Soils in the valleys are dark grey heavy clays. They are strongly acidic in reaction to the low status of organic matter, low moisture-holding capacity, and low fertility level.

3.29 Northern and Eastern Hills

This region includes the country's hill areas, which occupy about 12 % of the total area of Bangladesh. The area of this region is 18,171 km^2. This tract mainly covers Khagrachhari, Chittagong Hill Tracts, Bandarban, Cox's Bazar, and small areas along the northern border of the Sherpur, Mymensingh, Sunamganj, and Sylhet districts. In general, slopes are very steep, but more rolling relief occurs locally and a few low hills have flat summits. Relief is complex. Hills have been dissected to different degrees over different rocks. The hills are mainly excessively well drained. The valley soils are poorly drained and subject to flash floods. The soils are yellow–brown to strong brown, permeable, friable, loamy, very strongly acid, and low in moisture-holding capacity. In general, slopes are very steep and brown hill soil is the predominant general soil type of the area. The organic matter content and general fertility level are low.

3.30 Akhaura Terrace

This region occupies major parts of the eastern border of Brahmanbaria and minor areas of the southwest corner of the Habiganj district. It covers an area of 113 km^2. The land is mainly broad and level, standing 3–6 m above piedmont valleys. Upland soils are mainly moderately well drained, but lowlands are seasonally shallowly flooded. The main soils in the uplands have strong brown clay. The valley soils range from silty clay to clays. Deep red brown terrace soils, grey piedmont soils, and acidic basin clays are the major components of the general soil types of the area. The general fertility including organic matter status is low. The soils are strongly acidic in reaction.

The above classifications will, however, need readjustment in the near future due to the effect of global climate change. It has already been assessed that the area under salinity has encroached deeper inside the mainland. Changes due to anthropogenic activities are also visible. Construction of highways, dams, polders, and industrial and urban settlements have already shown marked microlevel changes.

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4 Geology and Geomorphology

4.1 Geology

Geology deals with the nature and properties of rocks and sediments. Information on the geology of the rocks and sediments is essential to an understanding of the nature and properties of the parent materials in which the soils of the country have developed. It is also essential to an understanding of the geomorphology of the country. The geology of Bangladesh is affected by the location of the country, as Bangladesh is a riverine country. The rivers are the most significant features of Bangladesh geology as they constantly change course, sometimes rapidly. As a result the topological features of Bangladesh are ever changing.

There are three major geological formations in Bangladesh that are important in relation to soils. These are: (i) tertiary hill sediments in the northern and eastern hills; (ii) the Madhupur clay of the Madhupur and Barind Tracts in the central area and the west; and (iii) the recent alluvium in the floodplain and estuarine areas occupying the remainder of the country (Brammer 1996).

4.1.1 Tertiary Hill Sediments

These sediments comprise mainly the unconsolidated and little consolidated beds of sandstones, siltstones, shales, and some conglomerates. They have been folded into a succession of pitching anticlines and synclines. These are aligned approximately north–northwest to south–southeast in Chittagong and the south of Sylhet districts, swinging around to almost east–west in the north of the Sylhet and Mymensingh districts (where, in the extreme north, they form part of a monoclinal fold along the southern margin of the Shillong plateau of Assam). These folds are interrupted by major linear and transverse faults in places. The rocks generally have steep dips, except in the center of the synclines. The frequent changes in lithology from sandstone to shale, and the close dissection of the hill ranges they occupy, provide complex soil patterns in many areas.

The higher ranges in the Chittagong and Sylhet hill areas are underlain by rocks of the Surma and Tipam formations considered as late Oligocene to mid-Miocene in age. They comprise mainly shales and siltstones, consolidated to varying degrees, locally calcareous, and sometimes pyritiferous. Lower hill ranges are mainly underlain by few consolidated sands and shales of the Dupi Tila formation, probably of mid-Miocene to Pliocene age. Smaller areas are occupied by the Dihing formation, of Pliocene to Pleistocene age, which includes pebble and boulder beds along the northern border of the Sylhet and Mymensingh districts.

The sand fraction of these rocks is dominated by quartz (70–90 % of total). Feldspar (mainly alkali) and mica contents are generally low (1–10 % and less than 5 %, respectively). Heavy mineral contents generally do not exceed 3 %. They comprise mainly zircon, tourmaline, kyanite, staurolite, and epidote, in varying proportions. The total content of easily weatherable minerals (feldspar plus biotitics) is generally less than 10 %.

Exceptionally, in some younger rocks along the northern border of Mymensingh district, higher contents of feldspar (up to 15 %) are found and relatively high amphibole and biotitic contents occur in the heavy mineral assemblage. The total content of easily weatherable minerals in these rocks generally exceeds 15 %. Boulders seen in Dihing rocks in the north of the Sylhet district included some from basalt and gneisses, as well as a majority from Eocene sandstones of the Barail formation. These rocks are exposed in the Shillong plateau to the north.

Clay mineral data available for the Chittagong Hill Tracts suggest that kaolinite is the dominant fraction with minor amounts of illite and vermiculite.

4.1.2 Madhupur Clay

This formation underlies the Madhupur and Barind tracts. It possibly also occurs on the Akhaura terrace area and on the summit of the Lalmai Hills in the east of Comilla. The

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formation is remarkably homogeneous in appearance, both vertically and laterally. It comprises a layer of unconsolidated clay, about 10 m thick near Dhaka, but apparently thinner to the east and possibly much thicker in the west of the Rajshahi district. The formation is generally almost horizontal, but has been broken into a number of fault blocks, some of which are slightly tilted. Extensive areas of the Barind Tract and parts of the Madhupur Tract have almost level terracelike topography. The western part of the Barind Tract and considerable parts of the Madhupur Tract are closely dissected.

The Madhupur clay was earlier called the older alluvium and was regarded as being from the Pleistocene age. The 1964 Geological Map of Pakistan gave the formation the name Madhupur clay and suggested that it might correlate with the Dupi Tila formation, officially regarded as being from the Mio-Pliocene age. This correlation is apparently supported by close mineralogical similarities between these formations.

In some places, the Madhupur clay has been considerably altered by weathering and converted into red mottled clay. Where it is less altered, it comprises a grey heavy clay, very slick-sided, usually with a few small, hard, iron-coated manganese concretions scattered throughout, and sometimes with numerous large, hard, lime nodules distributed irregularly in the upper part. The slick-sided iron–manganese concretions and lime nodules seem to have developed under different climatic and geomorphological conditions from the present, possibly in the late Pleistocene.

The sand mineralogy of the Madhupur clay is broadly similar to that of the Tertiary hill sediments. It is very different from that of adjoining floodplain deposits. The Madhupur Tract and the eastern part of the Barind Tract are similar in mineral content to the major part of the Tertiary sediments: high in quartz, relatively low in feldspar and mica, and with zircon, tourmaline, kyanite, staurolite, sillimanite, and epidote dominating the heavy mineral fraction. The content of easily weatherable minerals ranges from 4 to 9 %. The western half of the Barind Tract has a slightly higher content of easily weatherable minerals (8–14 %) and a different heavy mineral assemblage: garnet occurs in addition to kyanite, staurolite, sillimanite, and epidote in the south; in the north, sillimanite is dominant and epidote contents are small.

Clay mineral data for unweathered Madhupur clay (near Dhaka) indicate that it comprises illite, kaolinite, and a trace of montrorillonite. This mineralogical composition suggests that the Madhupur clay is similar in origin to the Tertiary rocks. The low feldspar and mica contents in comparison with floodplain sediments suggest that it was formed either before the major uplift of the Himalayas to the north or from crystalline rocks similar to those of the Rajmahal hills and the Shillong plateau which may formerly have linked these two massifs, but which may subsequently have been downfaulted. The latter alternative seems more likely.

4.1.3 Recent Alluvium

Unconsolidated floodplain sediments occupy the greater part of the country. These sediments are far from homogeneous in age, texture, and mineralogy. They have been deposited under piedmont, meander floodplain, estuarine, and tidal conditions in different areas. New alluvium is still being deposited near active river channels, but most floodplain land has apparently received little or no new alluvium for several hundred years or more. Rivers have changed their courses from time to time in the past, abandoning and reoccupying various parts of their floodplains, areas have also been uplifted or downwarped by earth movements, especially in the Sylhet and Mymensingh districts, and there are numerous, sand-filled, earthquake fissures in parts of these districts.

Most floodplain sediments have a high silt content. This is particularly so in the case of Brahmaputra, Jamuna, and Meghna sediments. Sandy sediments occur extensively in the substratum of soils in the north of the Tista floodplain and the west of the Ganges floodplain. Clay deposits occur on the surface over most of the Ganges floodplain. Peat has accumulated in some permanently wet basins throughout the province, usually shallowly, but up to 5-m thick in parts of the Gopalganj–Khulna peat basins.

The Ganges, Brahmaputra, and Tista, and rivers draining the northern and eastern hill areas, bring in sediments derived from areas of different geology. In brief, Ganges, Brahmaputra, and Tista sediments are characterized by having large mica content (both muscovite and biotite), whereas sediment derived from the northern and eastern hill areas are generally much less micaceous. Ganges alluvium is calcareous, but other sediments are not except where partially mixed with Ganges alluvium. Deposits of the Tista, Brahmaputra, and Ganges Rivers are strikingly different from those derived from hill and terrace areas. They usually contain 15–30 % feldspar (equally divided between alkali and plagioclase varieties) and 5–30 % mica. The amount of mica varies with the size fraction, some silty deposits containing as much as 80 % mica in the associated sand fraction. The heavy mineral content ranges between about 2 and 9 % and the content of easily weatherable minerals range from about 25 to 40 %.

In floodplain deposits of the Brahmaputra, Jamuna, Meghna (estuarine and river floodplain), and part of the Karatoya–Bangali, as well as beach sand deposits in the south of the Patuakhali district, amphiboles (45–70 %) and epidote (15–30 %) predominate in the heavy mineral assemblage. Biotite generally provides 65–75 % of the total

mica content. Ganges deposits have relatively lower amphibole (35–40 %) and high garnet (more than 20 %) contents in the heavy mineral assemblage. They also contain dolomite and calcite fragments. Tista deposits have a high content of biotite (45–75 % of the heavy fraction, but 10–30 % in old Himalayan piedmont deposits). Tista sediments differ from Brahmaputra sediments in having a lower epidotic and higher biotite content and from Ganges sediments in having higher contents of biotite and sillimanite.

Floodplain deposits of the Surma and other eastern rivers are generally similar to those of the Tertiary hill formations. They are low in feldspar and mica, and their content of easily weatherable minerals in usually about 10 %. However, some piedmont rivers, such as the Someswari and Matamahuri, bring in material richer in amphiboles. Deposits in the Sylhet basin are also richer in amphiboles (25–55 % of the heavy fraction) than most alluvium derived from Tertiary hill areas. At the same time, they are richer in epidote (20–40 %) and zircon than the Brahmaputra deposits.

The clay mineralogy of the floodplain sediments is also strikingly different from that of hill and terrace sediments. Tista, Brahmaputra, and old Meghna estuarine alluvia have a mixture of kaolinite, illite, and chlorite. Ganges and young Meghna estuarine alluvia have these same clay minerals, together with an important amount of montmorillonite.

4.2 Geomorphology

There are three geomorphologic division of Bangladesh *vis-à-vis* its soil formation. These are:

A. Flood plain areas (80 % of the country)
B. Terrace areas (8 % of the country)
C. Hill areas (12 % of the country) (Hussain 1992).

4.2.1 Floodplain

The floodplain constitutes about 80 % of the total land surface of Bangladesh. It is formed by the sediments deposited by the major rivers of Tista, Brahmaputura, Jamuna, Ganges, Meghna, Surma–Kushiara, Karotoa–Bangali, Atrai, Punarbhaba, and other small rivers. During the process of deposition of sediments under different environmental conditions, some differentiable landscapes are formed within the broad floodplain landscape. Five major types of floodplains are recognized: *active floodplain*, *meander floodplain*, *tidal floodplain*, *estuarine floodplain*, and *basin*.

4.2.1.1 Active Floodplain

The active floodplain includes *charlands* (land accreted in rivers), either isolated or attached to the young alluvial mainland along the Tista, the Ganges, the Brahmaputura, and the Jamuna. Each active floodplain is named after the big river by which it is formed. The area is quite hazardous because the land is exposed to severe river erosion, rapid flow of floodwater over the land, burial of new deposition of sediments almost every year on agricultural land, and flooding is mainly deep to very deep in the monsoon season.

4.2.1.2 Meander Floodplain

The meander floodplain covers the most extensive areas within the floodplain areas. They are stable mainlands formed in the subrecent years by the sediments of the big rivers. Those floodplains are named after the big rivers that have deposited sediments and have formed a landscape characteristic of their own. Based on the differences in landform, hydrology, and soils, they are subdivided into the Tista River floodplain, Karotoa–Bangali River floodplain, Brahmaputura River floodplain, Ganges River floodplain, and Meghna River floodplain.

Tista Floodplain

The Tista floodplain comprises a variety of small landscapes that were created as the Tista River formed and abandoned successive channels across the area. At different times in the past, the Tista had been flowing through the channels now named the Punarbhaba, Mahananda, Atrai, Karotoa, Little Jamuna, and Ghagat Rivers. Soils are olive brown, readily permeable, loamy on the higher sites, and grey or dark-grey, slowly permeable, heavy silt loams or silt clay loams on the lower lands. The fertility of these soils is moderate to good, although in places they have a deficiency of sulphur.

Karotoa–Bangali Floodplain

The Karotoa–Bangali floodplain is, in fact, a part of the Tista and the Brahmaputura floodplain. The boundary is arbitrarily drawn to differentiate the area where the parent soil material is apparently a mixture of the Tista and the Brahmaputura alluvia. Soils of this area are loamy in the northern part, mainly in the Bogra district where there is a smooth landscape of broad ridges and shallow basins; alongside the Bangli river in the east of Sirajganj district, the relief is locally more irregular where the soil is highly permeable and sandy, and in the west of the Sirajganj district, soils are impermeable and heavy clayey.

Brahmaputura Floodplain

The Brahmaputura floodplain constitutes two landscapes: the young Brahmaputura–Jamuna floodplain and the Old Brahmaputura floodplain. Until 200 years ago, the main channel of the Jamuna River flowed eastward across the former Mymensingh district and joined the Meghna River near Bhairab Bazar.

Ganges Floodplain

The Ganges floodplain characteristically has two landscape units: the high Ganges floodplain and the low Ganges floodplain. Highland soils are permeable, calcareous sandy and the lowland soils are heavy clayey. Heavy clay soils in the basins stay wet in the early dry season and then quickly become dry. Land preparation is difficult because of the heavy consistency of clay soil, which makes plowing difficult for dry crops or puddles unsatisfactory for transplanted rice crops.

Meghna Floodplain

The Meghna floodplain, a relatively small area, occurs in between the Meghna estuarine floodplain and the Brahmaputura floodplain. This area has two landscape units: the Middle Meghna River floodplain and the Lower Meghna River floodplain. Silt loams occupy relatively higher areas and silty clay loams occupy the depressions. Topsoils are strongly acidic and subsoils slightly acidic to slightly alkaline. The general fertility level is medium with medium to low organic matter, and N and K-bearing minerals.

Surma–Kushiara Floodplain

The Surma–Kushiara floodplain is formed by the sediments brought in by the rivers draining into the Meghna catchment areas from the northern and eastern hills. This floodplain has broad and smooth ridges and basins. Soils of the area are grey, slowly permeable, with silty clay loams to clay on the ridges. Soils of the medium lowland and lowland are relatively fertile but slow draining.

4.2.1.3 Tidal Floodplain

The tidal floodplain occurs mainly in the south of the Ganges floodplain but also on the parts of the Chittagong coastal plain, especially in the Chakoria Sundarbans at the mouth of the Matamahuri River. It has a distinctive, almost level, clay landscape crossed by innumerable interconnecting tidal rivers and creeks.

The tidal floodplain is formed under the influence of tidal flooding. The materials carried by tidal rivers are predominantly fine, so only narrow levees of very fine sand and silt are formed, and fine silts and clay are deposited in the extensive basins. Soils along the riverbank are grey, slightly calcareous, and loamy, but soils of extensive basin areas are grey or dark grey, noncalcareous, heavy silty clay. Soils of more than half of this area are slightly to strongly saline during the dry season. An extreme acid condition prevails in about one-third of the region but active acid sulphate soils occur in patches in some basins near the coastal areas where mangrove forest has been cleared for cultivation and the land has dried up.

4.2.1.4 Estuarine Floodplain

The estuarine floodplain occupies most of the Comilla and Noakhali districts, adjoining parts of the Barisal and Patuakhali districts, and small parts of the Dhaka and Sylhet districts. This land differs from tidal and meander floodplains in being almost level, lacking high ridges and deep basins and abandoned channels, lacking a close network of tidal creeks, and being almost uniformly silty throughout its extent. The land apparently originates as *char* (accreted land) formations within the open estuary and is built up by slow tidal sedimentation until such time as a change in the course of estuarine channels either erodes it or abandons it.

The estuarine floodplain has two landscapes: the Old Meghna estuarine floodplain and the Young Meghna estuarine floodplain. The soils of the Old Meghna estuarine floodplain are dark-grey to black and relatively fertile. The Young Meghna estuarine floodplain soils are finely stratified silt loam throughout to a deeper depth.

4.2.1.5 Basins

Basins are low-lying areas that have an individual entity as a physiographic unit. A *basin* is a large, gentle depressional feature is bounded by the Old Brahmaputra floodplain in the west, the Meghalaya plateau's foothills in the north, the Sylhet high plain in the east, and the Old Meghna estuarine floodplain in the south. Numerous lakes (beels), large swamps, and *haors* (very large depressions) cover this saucer-shaped area of about 7,250 sq km. Five basins have been recognized. These are Lower Atrai basin, Lower Punarbhaba floodplain, Gopalganj–Khulna beels, Arial beel, and the Sylhet Basin.

The Lower Atrai basin is popularly known as *Chalan Beel*, a lowlying area between the Barind Tract and Ganges River floodplain in the northwest Bangladesh.

The Lower Punarbhaba floodplain is a lowlying relatively small area occurring at the extreme northwest edge of the Barind Tract. The area is subject to rapid, sometimes early, flooding by runoff from the adjoining High Barind Tract and the flash flood coming down the River Punarbhaba although the total rainfall is relatively low and the start of the monsoon season is much delayed.

The Arial beel occupies the lowlying basin between the Ganges and the Dhaleswari Rivers.

The Gopalganj–Khulna beels, known as peat basins, occupy a number of lowlying areas between the Ganges floodplain and the Ganges tidal floodplain. The beels are mainly deeply flooded by rainwater in the monsoon season. Peat soils are derived from partly decomposed aquatic grasses and reeds. The soils are low in nutrients and have low bearing capacity when wet but hard when dry.

The Sylhet basin that occurs within the Surma–Kushiara floodplain mainly comprises extensive, lowlying basins

popularly known as Sylhet haors. Almost all the areas are very deeply flooded.

4.2.2 Pleistocene Terrace

The terrace area includes the Madhupur and Barind Tracts. In the northernmost strip of the Rajshahi division, the Pleistocene upland merges with the piedmont of the Himalayas and in the district of Mymensingh slopes down to the alluvial plains. Pleistocene terraces cover an area of about 8 % of the total land surface of Bangladesh with an average elevation of more than 15 m above mean sea level.

4.2.3 Hills

Hill areas constitute 12 % of the total land surface of Bangladesh. Northern and eastern Tertiary hills cover most of the Chittagong Hill Tracts, some small parts of southern Habiganj, and the southern and eastern borders of Moulavi Bazar. Hill areas constitute 12 % of the total land surface of Bangladesh. The overall pattern of the northern and eastern hill ranges are long linear ridges running generally north–south along the eastern border of Bangladesh.

4.2.3.1 Northern and Eastern Hills

The northern and eastern hills have mainly two kinds of landscapes: high hills more than 150–1,000 m high above mean sea level (MSL) with very steep slopes and low hills less than 150 m high with steep to rolling topography. High hills are often susceptible to landslides during heavy rainfall in the monsoon season. Soils are very strongly acidic and sandy. Soils of low hills are strongly acidic and sandy in texture.

4.2.3.2 Akhaura Terrace

The Akhaura terrace, part of the Tripura hill, occupies a small area along the eastern border of Bangladesh. It has mainly broad, level, upland areas standing 3–6 m above broad piedmont valleys.

Different landscapes of Bangladesh and their uses are presented in the Figures 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8 and 4.9.

Fig. 4.1 A field with transplant rice

Fig. 4.2 Broad valleys with transplant rice

Fig. 4.3 Piedmont area under tranplanted aman rice

Fig. 4.4 Sugarcane grown on higher ridge landscape

Fig. 4.5 Tea garden in Sylet

Fig. 4.6 Upland used for vegetables cultivation

Fig. 4.7 Upland used for improvised vegetables cultivation

Fig. 4.8 Landscape showing the stubbles left *in situ* after rice harvest (foreground) and vegetables cultivation (far)

Fig. 4.9 A landscape of the hill tracts dissected by lakes in the south-eastern part of Bangladesh

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5 Major Soil Types

A *general soil type* is a group of soils that are broadly similar in appearance and characteristics because they have developed in response to similar environmental factors such as climate, physiography, and drainage. This is a national classification system, designed to make distinctions that appear significant for understanding the formation, distribution, and use of the soils of Bangladesh. The general soil types represent a very broad level of generalization. It is a nontechnical grouping of soils, made originally to enable nonspecialists to make use of the technical information generated through reconnaissance soil survey work. The bases of the general classification are the physiographic units (Fig. 5.1) of the country. Most general soil types include several different soils that may have developed in more than one kind of parent material and may include a wide range of physical and chemical properties (Brammer 1996). Figure 5.2 shows a map of the general soil types of Bangladesh. The general soil types have been described with reference to their occurrence, geographic distribution, morphology, land use, and cropping pattern (FAO 1985). A total number of 21 general soil types have been recognized that are distributed on three geomorphologic units. Fourteen general soil types have been identified on floodplain areas, six on terraces, and one on hilly areas. The areas of the general soil types and a brief description are given in Fig. 5.2 and Table 5.1. These areas vary widely, ranging from as small as 342 km^2 (brown mottled terrace soils) to as large as 33,872 km^2 (noncalcareous grey floodplain soils). Noncalcareous grey floodplain soils occupy about one-fourth of the total area of Bangladesh. Noncalcareous dark grey floodplain soils and calcareous dark grey floodplain soils together constitute around 44 % of the total land area of Bangladesh. Organic soils occupy only a relatively small area (<1 %) of the country.

5.1 Calcareous Alluvium

These are young soils formed on freshly deposited alluvium of the Ganges and Lower Meghna Rivers that are stratified within 25-cm from the ground surface and contain lime. Soils are stratified or there is raw alluvium throughout or below the cultivated layer. They are calcareous throughout or part of it and lack a diagnostic subsoil horizon. This alluvium on the active Ganges floodplain mainly comprises brownish grey to pale brown sandy and silty deposits, which are moderately calcareous. The top soil is found to have a greyer color and be iron-stained along root channels in places where rice is cultivated. Soils of the Ganges floodplains are moderately to deeply flooded by river water during the rainy season, whereas the soils of the Meghna estuary are flooded by tidal water from the sea. Soils on the Lower Meghna estuarine floodplain are slightly calcareous grey to olive, finely stratified silts. They are mainly calcaric fluvisols.

The agricultural productivity of these soils ranges between moderate and poor. They are more productive and the potentiality is higher than the noncalcareous alluvium. New loamy and clayey Ganges River deposits are more friable and more easily suitable for crop cultivation, especially for dry land *robi* (dry season) crops and jute. Large areas of relatively older soils on the Young Meghna estuarine floodplain are well suited for paddy cultivation, especially transplanted *aman*.

5.2 Noncalcareous Alluvium

These soils occupy extensive areas on the active Tista and Brahmaputra–Jamuna floodplains. In these soils, there are

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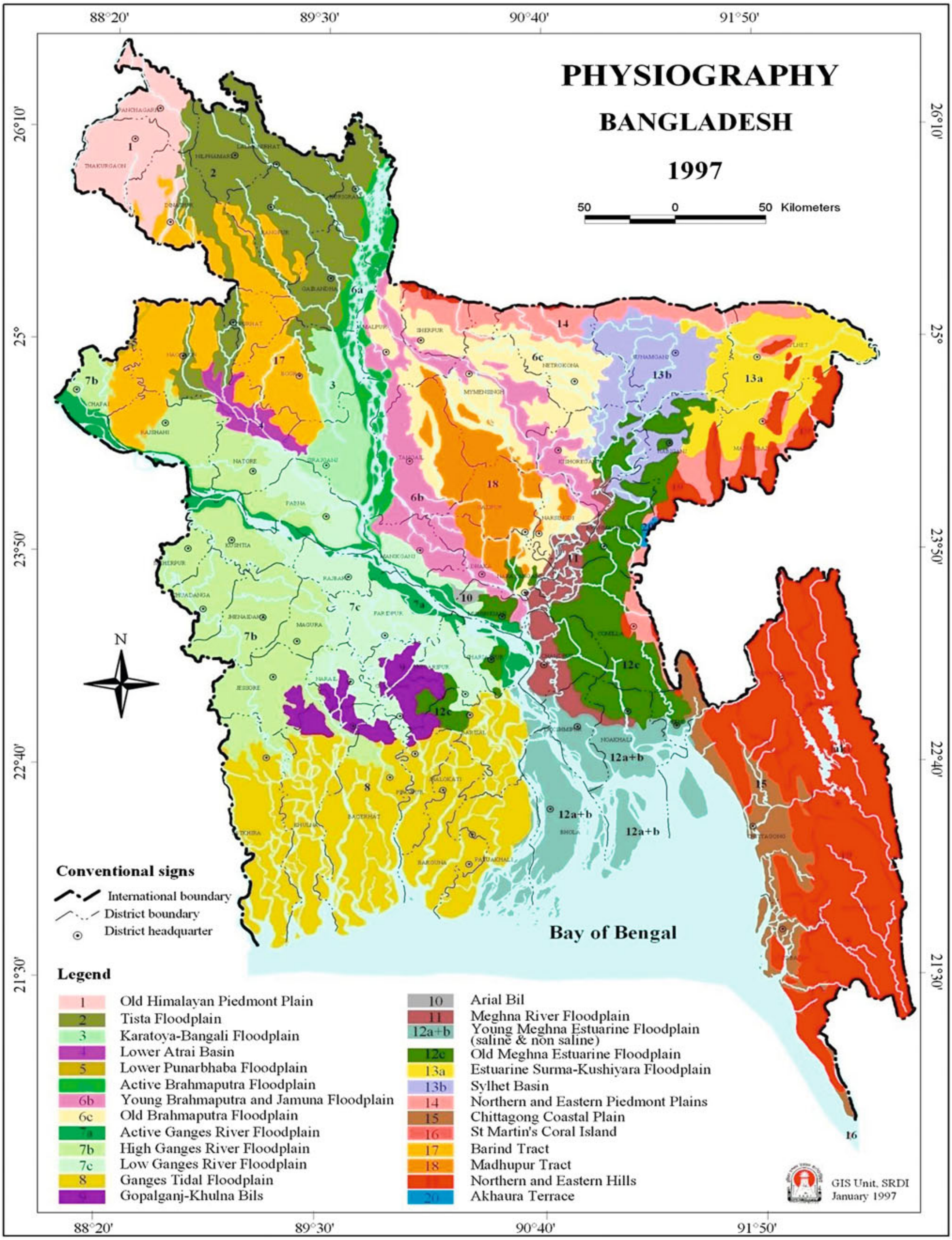

Fig. 5.1 The physiographic units of Bangladesh (*Source* SRDI)

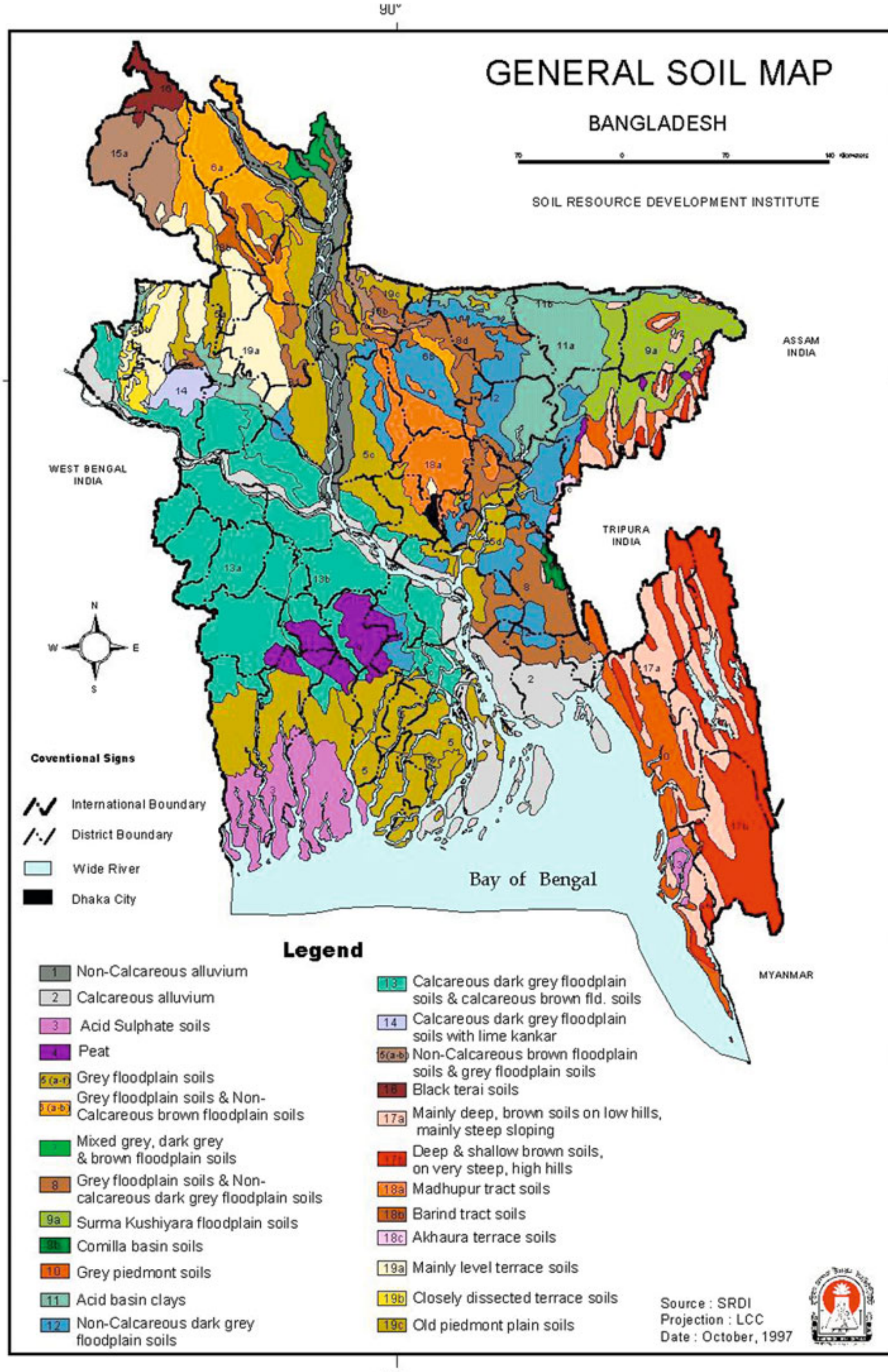

Fig. 5.2 General soil map of Bangladesh (*Source* SRDI)

no calcareous materials within the upper 125 cm of the soil profile. The soils are generally neutral to alkaline in reaction, but do not contain lime. The alluvial deposits are mostly silty, but sands occur on Brahmaputra–Jamuna river *chars*. Soils formed on the active floodplains are sandy or silty with grey to olive grey color, whereas soils on floodplain basins have silty clay loam to clay texture. Most of these soils have been included as eutric fluvisols.

Noncalcareous alluvium soils are mainly shallowly to deeply flooded by river water in the monsoon season, but old beach sands and soils on high floodplain ridges lie above normal flood levels. Except in deep sandy deposits, permeability generally is slow or very slow because of stratification in the upper layers and the presence of unripened alluvium at a shallow depth. New silty material impedes root development on recently deposited alluvium as the roots are

Table 5.1

No.	General soil types	Area (km^2)	Percentage of area
	Floodplain soils		
1	Calcareous alluvium	5,918	4.1
2	Noncalcareous alluvium	5,622	3.9
3	Calcareous brown floodplain soils	4,785	3.3
4	Calcareous grey floodplain soils	1,707	1.2
5	Calcareous dark grey floodplain soils	14,347	9.9
6	Noncalcareous grey floodplain soils	33,871	23.4
7	Noncalcareous brown floodplain soils	3,833	2.6
8	Noncalcareous dark grey floodplain soils	15,996	11.0
9	Black terai soils	834	0.6
10	Acidic basin clays	3,490	2.4
11	Acidic sulphate soils	2,266	1.6
12	Peat	1,300	0.9
13	Grey piedmont soils	2,053	1.5
	Area of floodplain soils	**96,022**	67.1
	Hill soils		
14	Brown hill soils	**15,615**	10.8
	Terrace soils		
15	Shallow red-brown terrace soils	725	0.5
16	Deep red-brown terrace soils	1,894	1.3
17	Brown mottled terrace soils	342	0.3
18	Shallow grey terrace soils	2,654	1.8
19	Deep grey terrace soils	3,522	2.4
20	Grey valley soils	1,143	0.8
	Area of terrace soils	**10,280**	7.1
21	Made land	1063	0.7
	Total soil area	**122,980**	85.0
	Miscellaneous land		
	Water bodies	9,734	6.7
	Urban lands	819	0.6
	Homesteads	11,227	7.7
	Miscellaneous land types	21,780	15
	Total	**144,760**	100

Source FAO/UNDP 1988

poorly aerated. The agricultural productivity of these soils is generally moderate to low. A plowpan is usually formed where transplanted *aman* is grown. Mottles occur along the root channels. The main limitations are the risks of flood damage, bank erosion, and burial by new alluvium.

5.3 Calcareous Brown Floodplain Soils

These soils occur on the upper parts of ridges on the Ganges River floodplain. Small areas occur on the Lower Meghna River floodplain and on the Ganges tidal floodplain. The topsoil usually is grey where rice is grown, brown where other crops are grown, and dark grey where sugarcane or other vegetables are heavily manured. Most topsoils are calcareous, but some are noncalcareous. The reaction usually is moderately alkaline, but may be slightly acidic to mildly alkaline, if the topsoil is decalcified. The subsoil is olive-brown. The prismatic structure is developed in relatively heavier soils, and thin, grey, subsoil coatings are sometimes found. Soil texture on the higher ridges usually is silt loam and occasionally sandy loam. Lower sites usually have silt loams or silty clay loams with a finer texture in the top soil than in the subsoil. The agricultural potential of these soils ranges from

high to low. The potentiality is highest in deep loamy soils where irrigation is available, and lowest in shallow ridge soils and in soils affected by salinity or strong alkalinity. Most of these soils belong to chromic–calcaric gleysols.

5.4 Calcareous Grey Floodplain Soils

These soils occupy parts of the Ganges tidal floodplain, mainly in the southwest and small areas on the Ganges and Lower Meghna River floodplains. They contain lime in part or all of the upper 125 cm of the profile. The topsoil usually is grey or olive-grey when dry, but may be darker and bluish or greenish grey when wet and reduced in the monsoon season. The subsoil usually is grey with yellow-brown or brown mottles and broken or continuous grey coatings. The structure usually is prismatic in coarse soils and blocky in clayey soils. Extensive areas of these soils on the Ganges tidal floodplain become saline in the topsoil during the dry season. Seasonal flooding is mainly shallow and fluctuates with the tides on the Ganges tidal floodplain and Lower Meghna River floodplain. Elsewhere, flooding is mainly moderately deep. Flooding is mainly by fresh water. Permeability is slow in the top soil because of the presence of plowpan. These soils are classified as chromic–calcaric gleysols.

5.5 Calcareous Dark Grey Floodplain Soils

These soils occur extensively in basins and on the lower parts of ridges on the Ganges floodplain. The soils in ridges are friable, oxidized, calcareous, and loamy, but the soils are dark grey, decalcified with heavy clays in basins. They are found within 125 cm of the soil surface and have dark grey subsoil coatings. The topsoil usually is about 15 cm thick, with a weakly developed plowpan at the base. Seasonal flooding ranges from shallow on the ridges to moderately deep to deep in basins. Flooding is predominantly by rainwater or the raised ground watertable. There are brown mottles along root channels. These soils have thick, yellow to red, bacterial iron coatings in the lower parts. The topsoils in ridges contain lime and are moderately alkaline in reaction. However, the topsoils become strongly to extremely acidic in the dry season when decalcified. Whether alkaline or acidic in the dry condition, the topsoils become reduced and neutral in reaction when they are submerged in the monsoon season. The structure is coarse prismatic which breaks down to coarse blocky, and a fine blocky or lenticular structure. Most soils of this type are clays, but the clay content varies with position on the relief. The soils in ridges are mainly silty clay loams to silty clays. Basin soils are heavy clays, often with clay contents of 70–80 % in the upper layers. The moisture-holding capacity generally is moderate. They are classified as chromi–calcaric gleysols.

5.6 Noncalcareous Grey Floodplain Soils

These are most extensive soils in the country, occupying most of the Tista, Jamuna, Karatoya–Bangali, eastern Surma–Kushiyara, and Middle Meghna River floodplains and the Ganges tidal floodplain as well as part of the Old Brahmaputra floodplain, Old Meghna estuarine floodplain, Sylhet basin, and the Chittagong coastal plain. The topsoils consist of 5–10-cm thick layers. These layers are grey or olive-grey when dry, but darker when wet, and are medium to very strongly acidic in reaction when dry, but neutral in the reduced condition. The subsoils are 15–50-cm thick and have coarse prismatic structure. Clay subsoils have a blocky structure. The soil texture varies both within the profile and on different positions of the floodplain relief. The topsoil generally is lighter in texture than the subsoil. On most floodplains, the highest ridge soils have a silt loam texture and the basin soils are silty clay loam to silty clays. These soils are seasonally flooded. In most areas, flooding is by rainwater or the raised groundwater table. The moisture-holding capacity is moderate to high in silt loam and silty clay loam soils. Shallow-depth soils or soils with plowpan have a low moisture-holding capacity. These soils are among the most productive soils in the country. In general, they are suitable for both dryland crops as well as paddy cultivation. These soils have been included in areni–eutric gleysols.

The general soil types and their diagnostic properties are summarized in Table 5.2.

5.7 Noncalcareous Brown Floodplain Soils

These soils occur largely on the Old Himalayan piedmont plain, in the north of the Tista floodplain, and more locally on the Old Brahmaputra floodplain and in some sandy deposits on the northern and eastern piedmont plains. The topsoil is dark brown to dark grayish brown. This layer is medium to strongly acidic in reaction. In the old piedmont deposits, the subsoil is dark yellowish-brown and usually 60–90-cm thick. Elsewhere, it is brown or tallow-brown and may be 30-cm thick. The subsoil is medium to strongly acidic in reaction. The substratum usually consists of pale-colored loose sand. There is little or no difference between the topsoil and subsoil texture in the Old Himalayan piedmont plain. The soils are sandy loams on the highest ridges and silt loams on the lower ridges. However, there is a significant difference in texture between the topsoil and subsoil in the Tista and Old Brahmaputra floodplains. The

Table 5.2

	Floodplain soils	
1	Calcareous alluvium	Raw or stratified alluvium; calcareous throughout or within 125 cm from surface
2	Noncalcareous alluvium	Raw or stratified alluvium; not calcareous or sulphidic within 125 cm from surface (generally neutral to moderately alkaline)
3	Calcareous brown floodplain soils	Moderately well to imperfectly drained floodplain ridge soils with an oxidized cambic B horizon; calcareous throughout or within 125 cm of the surface
4	Calcareous grey floodplain soils	Seasonally flooded soils with a cambic B horizon which is dominantly grey and/or has prominent grey gleyans; calcareous throughout or within 125 cm of the surface
5	Calcareous dark grey floodplain soils	Seasonally flooded soils with a cambic B horizon which is either dominantly grey and/or has prominent grey gleyans or pressure faces; calcareous within 125 cm of the surface. Many basin soils have a neutral to acid topsoil and a neutral subsoil over a calcareous substratum at 40–60 cm
6	Noncalcareous grey floodplain soils	Seasonally flooded soils with a cambic B horizon which is dominantly grey and/or has prominent grey gleyans; not calcareous within 125 cm of the surface. The topsoil generally is slightly to very strongly acidic (when not submerged); lower layers generally are slightly acidic to moderately alkaline
7	Noncalcareous brown floodplain soils	Moderately well to imperfectly drained floodplain ridge soils with an oxidized cambic B horizon; not calcareous within 125 cm of the surface. Topsoil and upper subsoil generally are medium to strongly acidic; lower layers are less acidic to neutral
8	Noncalcareous dark grey floodplain soils	Soils similar to noncalcareous grey floodplain soils but with a dark grey cambic B horizon and/or dark grey gleyans
9	Black terai soils	Imperfectly to poorly drained soils with a very dark brown to black topsoil more than 25-cm thick. A brown cambic B horizon occurs in soils where the dark A horizon is less than about 90-cm thick. Medium to strongly acidic in upper layers; less acidic to neutral below
10	Acid basin clays	Poorly or very poorly drained, grey or dark grey heavy clays with a cambic B horizon; very strongly or extremely acidic (pH < 5) to 50 cm or more, but not sulphuric or sulphidic
11	Acid sulfate soils	Poorly or very poorly drained, grey or dark grey soils with or without a cambic B horizon, which are actually or potentially toxically acidic (pH < 3.5) within 125 cm of the surface
12	Peat	Very poorly drained soils in which organic matter (peat or muck) comprises all or more than half of the upper 80 cm
13	Grey piedmont soils	Imperfectly to poorly drained soils in piedmont alluvium; similar to noncalcareous grey floodplain soils, but generally having a more prominently mottled subsoil which is medium to strongly acidic
	Hill soils	
14	Brown hill soils	Excessively to moderately well-drained soils with a yellow-brown to strong-brown (locally red-brown), cambic or argillic B horizon (except where very shallow), mainly overlying soft or fragmented rock at 50–100 cm. Mainly very strongly to extremely acidic throughout; sometimes less acidic in the surface layer or in weathering rock
	Terrace soils	
15	Shallow red-brown terrace soils	Moderately well to imperfectly drained, olive-yellow to strong brown soils with a cambic or argillic B horizon overlying grey, heavy, Madhupur clay at 25–60 cm. Mainly strongly to very strongly acidic, but very shallow soils locally contain lime nodules
16	Deep shallow red-brown terrace soils	Well drained to moderately well drained, red to yellow-brown soils with a cambic or argillic B horizon overlying a strongly red-mottled pervious clay substratum. Strongly to very strongly acidic throughout
17	Brown mottled terrace soils	Imperfectly drained soils similar to deep shallow red-brown terrace soils but with a strongly mottled pale brown and red subsoil overlying the dominantly red-mottled substratum
18	Shallow grey terrace soils	Poorly drained, grey, silty soils overlying grey, heavy, Madhupur clay at 25–60 cm. Slightly to strongly acidic in the silty topsoil and subsoil, becoming less acidic (locally calcareous) in the clay substratum
19	Deep grey terrace soils	Poorly drained, grey, silty soils, more red-mottled in the subsoil than the shallow soils and overlying a dominantly remottled, pervious, clay substratum. Mainly medium to strongly acidic throughout
20	Grey valley soils	Poorly drained, deep, grey, porous, silty soils occurring in terrace valleys
	Man-made land	
21	Man made	Soils on artificially raised cultivation platforms; better drained and more permeable than the subsoil materials from which they are derived, but broadly similar to them in other properties

agricultural potential of noncalcareous brown floodplain soils is mainly moderate to low. Most of these soils are dystric/eutric gleysols or cambisols.

5.8 Noncalcareous Dark Grey Floodplain Soils

These are the second-most extensive soils in the country. They do not contain lime in any layer within 125 cm of the surface. These soils occupy the Old Brahmaputra and Old Meghna estuarine floodplains, and locally the Tista, Karatoya–Bangali, Lower Atrai, Young Brahmaputra, and Lower Meghna River floodplains, and some basins on the Old Himalayan piedmont plain. They are differentiated from the noncalcareous grey floodplain soils by having dark grey instead of grey subsoil coatings, and from calcareous dark grey floodplain soils in being noncalcareous throughout the profile. The topsoils have surface layers 5–10-cm thick overlying a plowpan about 5-cm thick. These layers vary from grey to dark grey, and have rusty iron stains along root channels and cracks. The soils are medium to very strongly acidic in reaction when dry and neutral in the reduced condition. The subsoil usually is 20–45-cm thick. The upper part of these soils is dark grey having oxidized mottles. They have a strong coarse prismatic structure, but clay soils have an angular blocky structure. The subsoils are slightly acidic to moderately alkaline in reaction. The topsoil is much lighter in texture than the subsoil. The ridges are silt loam or silty clay loam, whereas basins are silty or clay in texture. The texture of the substratum usually is lighter than the subsoil. The substratum usually is neutral to moderately alkaline in reaction. The agricultural potential of these soils is highest on shallowly flooded ridge soils and lowest in deep basin centers.

5.9 Black Terai Soils

These soils occupy a small area on the Old Himalayan piedmont plain. Most of the soils are shallowly flooded in the monsoon, mainly by rainwater and the raised groundwater table. Depression soils are subject to flash floods from rivers crossing the old alluvial fan. The thickness of the topsoil ranges from 25 cm to more than 75 cm. The topsoil is very dark grayish brown to black. Where transplanted rice is practiced, the soil is slightly pale with a few grey and brown mottles. The cultivated layer is medium to very strongly acidic in reaction. The lower part is slightly to medium acidic. The substratum usually consists of white, grey, or very pale brown loose sand. This layer is slightly acidic to neutral in reaction. The texture of the topsoil and subsoil is uniform and both layers contain much more clay and silt than the substratum. The most extensive soils are sandy loam, but loams and sandy clay loams also occur on lower sites. The sand is predominantly medium and fine. These soils are rapidly permeable. The moisture-holding capacity is high, except in sandy and shallow soils. The agricultural potential of black terai soils is moderate to low. These soils are classified as chromi–mollic gleysols.

5.10 Acidic Basin Clays

These soils occur extensively on the Lower Punarbhaba floodplain, Lower Atrai basin, Arial beel, Surma–Kushiyara floodplain, Sylhet basin, and its piedmont basins. They also occur in the deep valleys of the Madhupur Tract. Most soils are deeply flooded with rainwater and runoff from the adjoining areas in the monsoon. The topsoil usually is 12–25-cm thick. It is grey to dark grey with yellow to red mottles along the root channels. These soils are heavy clay in texture, but silty clay loam or silty clay occurs in some places. Cultivated soils crack widely when dry. The subsoil is grey to dark grey with heavy clay and strong yellow to red mottles. The structure is coarse prismatic and blocky. The subsoil is very strongly to extremely acidic. The substratum occurs at variable depth, usually below 50 cm. This layer is usually silty and sometimes clayey, and is permanently wet and reduced. The reaction varies from extremely acidic to moderately alkaline. The agricultural potential of acidic basin clays is low. They are classified as eutric, dystric, or mollic gleysols.

5.11 Acidic Sulphate Soils

Acidic sulphate soils are formed in the tidal alluvium and are actually or potentially extremely acidic ($pH < 3.5$) within 125 cm of the surface. These soils occur in the Khulna and Chakaria Sundarbans, where former mangrove forest has been cleared for cultivation. Two kinds of soil are included in this type. One is tidally flooded with saline water throughout the year and is under mangrove forest and contains soft, finely stratified, muddy sediment layers. The other kind of soil occurs on land that has been cleared and brought under cultivation. Under field conditions, these soils are slightly acidic, but the pH decreases when dried. These extremely acidic soils are locally known as *Kosh* soils in the south of the Chittagong region. The agricultural productivity of acidic sulphate soils is severely limited due to the extreme acidity of these soils. Shrimp culture is more economic than agricultural use because of the high cost for reclamation. The soils are classified as either thionic fluvisols or thionic gleysols.

5.12 Peat Soils

Peat soils occur extensively in the Gopalganj–Khulna beels and locally in some haors of the Sylhet basin. In these soils, partially or wholly decomposed organic matter occupy more than half of the uppermost 80 cm of the profile. These soils have a low bearing capacity. Peat and muck layers are black to dark brown, strongly reduced, and neutral in reaction under natural conditions. These layers become extremely acidic when they are allowed to dry. They are seasonally flooded by rainwater and remain wet throughout the season. They become dry during the dry season where mineral topsoil is present. Mineral topsoils are mainly grey or dark grey and become strongly acidic under dry condition. The agricultural productivity of these soils generally is low. Under natural conditions, the land is used for reed production and fishing. They have been included as Histosols.

5.13 Grey Piedmont Soils

These soils occur on alluvial outwash fans at the foot of the northern and eastern hills and locally on the Chittagong coastal plain. Seasonal flooding is shallow, but they are severely affected by occasional flash floods by heavy rainfall. The topsoils have a 5–10-cm thick cultivated layer. They are grey to pale brown when dry and grey to olive-grey when wet. These layers are strongly to extremely acidic when dry, but neutral in reduced condition. The subsoils vary from 15 cm to more than 60 cm in thickness. They are grey with yellow-brown, brown, or red mottles. The structure is prismatic and blocky. The substratum comprises stratified material. Most soils are loamy in texture. They usually are more sandy close to hills, and more silty and clayey on the lower parts of the piedmont slopes. The topsoil usually is lighter in texture than that of the subsoil. The agricultural productivity of these soils is mainly moderate to low. Most soils except sandy ridge soils are much better suited for paddy cultivation than dryland crops. These soils are classified as dystric or eutric gleysols.

5.14 Brown Hill Soil

These soils occur on gentle to very steep slopes of northern and eastern hills. These soils have been developed over consolidated or unconsolidated rocks, which are imperfectly to excessively drained. The thickness of the topsoil ranges from 5 to 7.5 cm. Under forest vegetation, the color varies from dark grayish brown to grayish brown. Under cultivation, the surface layer is pale brown. The subsoil usually is 30–90-cm thick. In most cases, they have a cambic or argillic B-horizon. Generally the subsoils are yellow to strong brown, friable, porous, sandy loam to sandy or silty clay loam, and are very strongly to extremely acidic. The topsoil usually has less clay than the subsoil. The profile is strongly leached throughout. The agricultural productivity of these soils is mainly low for field crops, but ranges between low and high for tree plantation. The majority of these soils are dystric Cambisols and haplic and ferric Alisols.

5.15 Shallow Red-Brown Terrace Soils

These soils occur extensively on gently undulating to rolling relief on the Madhupur Tract and locally in the Barind Tract. Most of the soils are found under degraded *sal* (*Shorea robusta*) forest. These soils are imperfectly to moderately well drained. Under forest vegetation, a 2-cm thick surface layer is present having the properties of grey to brown, silty, platy structure and are slightly to strongly acidic in reaction. Under cultivation, the topsoil is 5–10-cm thick and is brown to strong brown, strongly to very strongly acidic, and clay loam or clay. The subsoil ranges from a porous yellow brown loam to olive brown, strong or reddish. The substratum comprises recognizable Madhupur clay which has a strong blocky structure and is plastic when wet and hard when dry. It is grey with red or brown mottles and is very strongly acidic. The agricultural productivity of these soils is low both for field crops and tree crops. The majority of them have been classified as haplic and gleyic Alisols.

5.16 Deep Red-Brown Terrace Soils

These soils occur extensively in the northeastern Barind Tract, on the Madhupur Tract and on the Akhaura terrace. The topsoil usually is 8–14-cm thick and has a brown to yellow-brown color, loam to clay loam texture, and rusty stains along root channels. The subsoil usually is 60–120-cm thick. The color is dark red on well-drained terrace and strong brown to yellow brown on moderately well-drained soils. This layer is clay in texture, porous, and very strongly acidic in reaction. The subsoil grades into the red-mottled substratum, with yellow, pale yellow, and pale brown mottles. Weatherable feldspar and biotite are present in small amounts in both the subsoil and the substratum. Kaolinite is the dominant clay mineral (about 60 %) with 20 % illite and 5–20 % vermiculite. The agricultural potential of these soils is mainly moderate or low for rainfed field crops, but moderate or high for irrigated field crops. They are classified as orthi-ferric Alisols.

5.17 Brown Mottled Terrace Soils

These soils occur on level terrace sites on the north and east of the Barind Tract, the Madhupur Tract, and the Akhaura terrace. These soils are brown and red-mottled, strong to extremely acidic, friable clay loam to clay soils over deeply weathered, red-mottled, Madhupur clay. They are moderately to imperfectly drained. The topsoil is 10–15-cm thick. The color is predominantly brown, with grey and stronger brown mottles. The soil is silt loam or loam in texture, and usually very strongly acidic in reaction. A strong plowpan is present in soils used for transplanted rice. They have been classified as ferric Luvisols and Alisols. The subsoil usually is 40–60-cm thick. The subsoil comprises brown or yellow-brown, friable, porous, clay loam to clay. The reaction is medium to very strongly acidic. The substratum usually is red, mottled with pale brown, friable, porous clay, and usually very strongly acidic in reaction. These soils have low agricultural potential for both dryland crops and for paddy cultivation. They are classified as orthi-ferric Luvisols.

5.18 Shallow Grey Terrace Soils

These soils occur extensively on the level Barind Tract and the high Barind Tract, but occur more locally on the Madhupur Tract. Most soils are shallowly flooded by rainwater or by a raised groundwater table. The topsoil is 10–15-cm thick, which is grey and silty, with yellow brown to strong brown mottles along cracks and root channels. It is strongly to very strongly acidic when dry, but neutral in reduced condition. A compact plowpan occurs below the cultivated layer. The thickness of the subsoil varies between zero and about 50 cm. It is grey, highly porous, silt loam to silt clay loam. The reaction is medium or strongly acidic throughout. The substratum has grey color mottled olive or red, heavy silty clay or clay texture and a strong blocky or wedge-shaped structure. The soils have low permeability because of the presence of compact plowpan. Lime nodules are found in some soils. These soils have moderate agricultural potentiality. The soils are well suited for transplanted paddy, especially with irrigation, but are poorly suited for dryland crops and for tree crops. They have been classified as chromi-eutric Planosols.

5.19 Deep Grey Terrace Soils

These soils occur in some central and western parts of the Barind Tract, locally on the Madhupur Tract, in the northeast of the Barind Tract and on parts of the piedmont plain in the north of the Mymensingh region. These soils are shallowly flooded with rainwater or raised groundwater. The topsoil is dark grey and silt loam or silty clay loam. Yellow-brown or strong brown mottles are found along root channels and cracks. The reaction is medium to strongly acidic when moist or dry, but neutral when submerged. The subsoil is grey, mottled yellow-brown, red and sometimes black, friable, highly porous, and silty clay loam to silty clay. The substratum is generally friable, porous, clay, and weakly structured. Thick grey coatings occur on ped faces and in pores in the lower parts of the subsoil and in the substratum. These soils have low agricultural potential. These soils are better suited for paddy cultivation than for dryland crops and are classified as chromi-albic gleysols.

5.20 Grey Valley Soils

These soils occur in the shallow valleys of the Madhupur and Barind Tracts. They comprise deep, grey, mottled, silt loam to clay soil. These soils are moderately to deeply flooded by local runoff of flood water. The topsoil is about 15-cm thick having the properties of grey silt loam or silty clay loam with yellow-brown to strong brown iron stains along cracks and root channels. The reaction usually is strongly to very strongly acidic in moist and dry conditions, but is neutral in reduced condition. The subsoil has a brightly oxidized, friable, silty layer up to 10-cm thick at the top and grades into 50–100 cm or more of grey, mottled yellow-brown to reddish brown, highly porous, silt loam or silty clay loam. The Grey Valley soils have a low to moderate agricultural potential.

5.21 Made-Land Soils

These include a miscellaneous group of soils. These soils are common in several parts of the country. The soils vary in properties according to the materials from which they are constructed. These materials are mainly derived from adjoining topsoil and subsoil material, or from deeper substratum material. Generally, the soils are loamy, but sandy, clay, and peat also occur. These soils are darker in color, more oxidized, friable, and permeable. Generally, they are more acidic. The organic matter content is low. There is no difference in texture between the subsoil and topsoil. The distribution of clay down to the profile is irregular. These soils have been classified as fimic anthrosols.

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6 Soil Properties

Soil is a heterogeneous mixture of silicate minerals, organic matter, and a variety of salts and oxides of metals. The silicate minerals vary in sizes from the finest colloid to very coarse dimensions.

Soil's physical, chemical, and biological properties are very much dependent on its formative nature and conditions, climatic conditions, and the anthropogenic situations that manage the soil. Bangladesh soils are thus no exception.

6.1 Soil Texture

The relative size of the soil particles is expressed by the term soil texture, which refers to the fineness or coarseness of the soil. More specifically, texture is the relative proportion of the different size groups or separates. Generally materials larger than 2 cm in diameter are called stones, materials between 2 cm and 2 mm in diameter are called gravel, and the materials smaller than 2 mm in diameter are called fine earth. The components of fine earth are sand (smaller than 2 mm but larger than 0.05 mm in diameter), silt (smaller than 0.05 mm but larger than 0.002 mm in diameter), and clay (smaller than 0.002 mm in diameter).

Soil texture depends on the types of the parent materials. The soils of Bangladesh have developed on preweathered alluvial materials that have been deposited at different geological periods. The content and distribution of soil particles in these soils are largely dependent on the lithology of the sediments deposited by the major river systems over different geological periods. The flood plains of both Gangetic and non-Gangetic alluvium contain 40–45 % clay that remain unchanged with depth. Tidal and estuarine floodplains contain a much higher content of clay and silt and remarkably low content of fine sand (<5 %) compared to meander floodplains. The terraces contain comparatively less clay in the topsoils (15–25 %) than do floodplains. Fine sand content in the terrace soils ranges from 10 to 25 % and 30 to 45 % silt. The smaller clay content may be due to the loss of clay from the surface horizon either by runoff or lithology of the sediments. The hill soils also have relatively low clay content down to approximately 20 cm depth. The loss of clay in well-drained hill soils occurs due to horizontal translocation of clay by runoff. Hill soils contain 10–60 % fine sand and 15–55 % silt in various profiles developed in different parent rocks.

The soils of Bangladesh are mainly loam in texture. Central and southwest parts of Bangladesh are heavy loam, whereas the north and southeastern parts are light loam in texture. The coastal areas of the south, southwest, and central parts are clayey in texture. Sandy soils occupy a small portion of the northern part of Bangladesh (Fig. 6.1) (FAO/UNDP 1988).

Texture is an important property of soil. The texture greatly determines the land use capability methods of soil management. For the study of morphology, genesis, classification, and mapping of soil, the knowledge of texture is important. In Bangladesh, both the USDA and the International System of Classification for textural classes are used. However, the USDA system is more commonly used.

In the floodplains of Bangladesh there is a general textural gradation from river bank to basin sides north to south with the fine-textured soils predominantly occurring towards the south. There is also textural gradation from river bank to basin sides. The major agricultural soils in Bangladesh have moderate textures with the majority ranging from loam or silt to silty loam to silty clay loam. Only a relatively few soils in Bangladesh belong to the extreme textural classes. With respect to textural aspects, the majority of the Bangladesh soils appear to be suitable for having quick resilience.

6.2 Soil Structure

The primary particles (sand, silt, and clay) of soil are bonded together into aggregates by cementing agents under natural soil conditions. The arrangement of the individual

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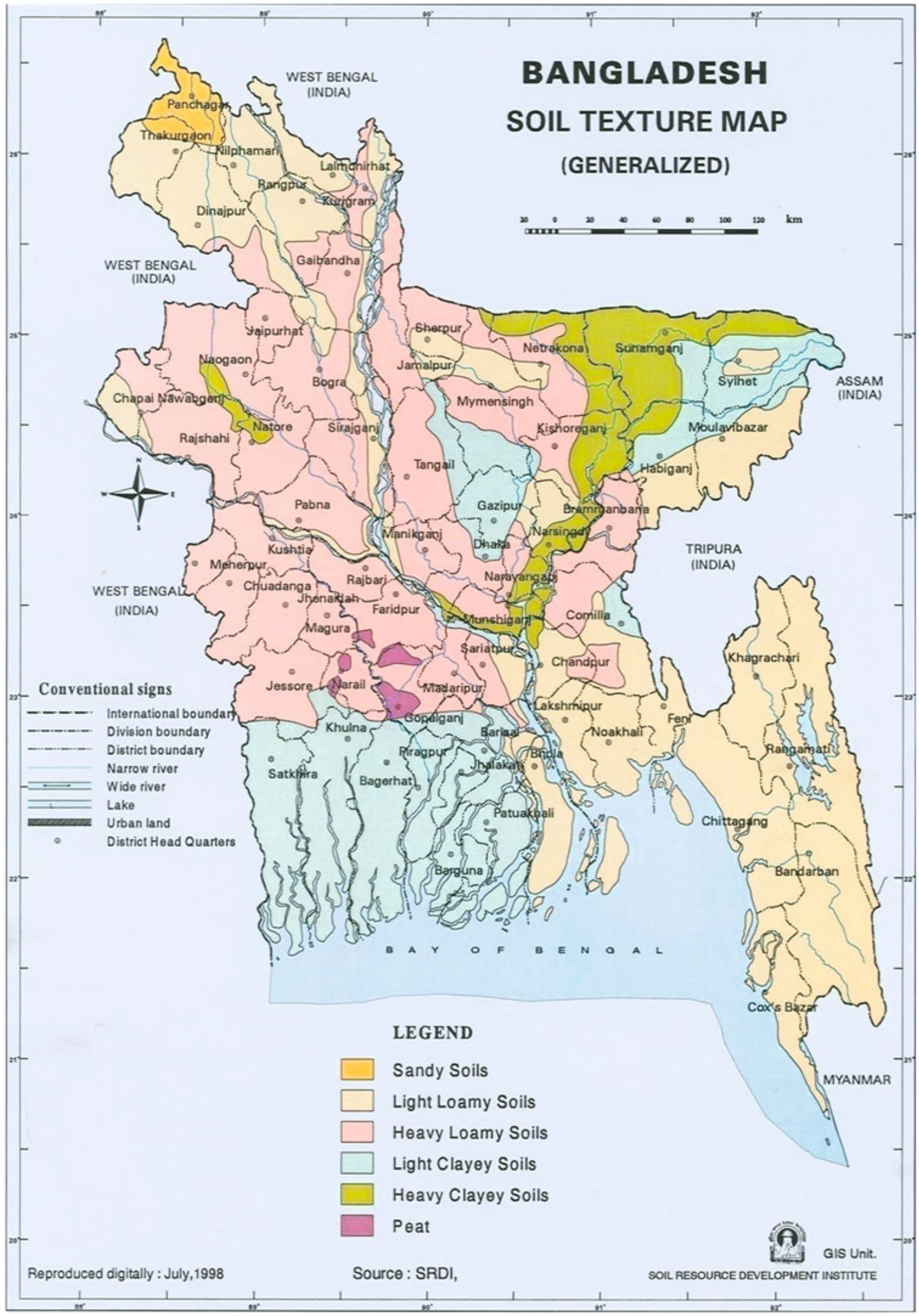


Fig. 6.1 Soil texture distribution of Bangladesh soils (*Source* SRDI)

soil particles with respect to each other into a pattern is called soil structure, the aggregation of soil particles into clusters of a definite pattern. As with texture, color, and other properties of soil, the structure of the different horizons of a soil profile is an important property. The aggregates of different sizes and shapes create soil pores of different sizes and shapes. Soil structure influences all plant growth factors. Water supply, aeration, root penetration, availability of plant nutrients, microbial activity, and other factors are all affected by soil structure.

6.2.1 Genesis of Soil Structure

The structure is the resultant of the arrangement and bonding of soil particles into some definite units and further arrangement and bonding of these units. The bonding between individual particles is generally considered to be stronger than the structural units themselves. The bonding of the soil particles into structural units is the genesis of soil structure. Clay plays the key role in the formation of soil aggregates. The degree of aggregation depends on the

amount of clay present. The bonding may be clay–clay particles or clay–silt plus sand through some forces or cementing agents. Organic matter plays the role of cementing agent. Soil organic matter contributes significantly to aggregation of soil particles. The degree of aggregation is positively correlated with the organic matter content. Soil humus consists of a number of polymeric substances that are polyelectrolytic in nature and have multiple charges. Water molecules are dipolar and colloidal soil particles are negatively charged. Thus water molecules are oriented and bridge the colloidal particles. The negative end of the water dipole is attracted to positively charged ions such as calcium and magnesium and the positive ends are attracted to the negative end of the clay particles. The orientation is given below:

$$\text{Clay}^{-} \ {-}^{+}\ \text{water}^{-} \ {-}^{+}\ \text{cation}^{+} \ {-}^{-}\ \text{Clay}^{-} \ {-}^{+}\ \text{water}^{-} \ {-}^{+}\ \text{cation}^{+} \ {-}^{-}\ \text{Clay}^{-} \ {-}^{+}\ \text{water}$$

Alternate wetting and drying leads to the formation of smaller aggregates, particularly in fine-textured soils. Drying causes shrinkage of the soil mass. When the dry soil mass is wetted, rapid intake of water causes unequal swelling throughout the soil mass which is fragmented along cleavage planes. By this process of wetting, entrapped air decreases in volume, thereby increasing the pressure of the entrapped air that causes disruption of the big clods into smaller ones.

Soil organisms play an important role in soil aggregation. During the decomposition of organic matter by microorganisms, various products are produced such as polysaccharides, organic acids, and gluelike substances. These products act in binding the soil particles to form aggregates. Plant roots also play an important role in the formation and stabilization of soil structure. When plant roots enter the soil, tremendous pressure is created on the soil particles causing the particles to become compact and aggregated. Decomposition of plant roots by microorganisms adds organic compounds and polysaccharides favoring cementation and aggregation of soil particles.

6.2.2 Types of Soil Structure

Soil structure is characterized in terms of the shape (or type), size, and distinctness (or grade) of the peds. The four principal shapes of soil structure are spheroidal, platy, prismlike, and blocklike.

Platelike. The horizontal dimensions are much more developed than the vertical axis resulting in a flattened, compressed lenslike appearance to the peds. When the units are thick, they are called platy and when the units are thin, they are called laminar.

Prismlike. The vertical axis is more developed than others, giving a pillar like shape. When the tops of the peds are rounded, they are called columnar and when they are plane, they are called prismatic.

Blocklike. All the dimensions are almost the same size and the peds are cubelike with flat or rounded faces. A blocklike structure has two subtypes: angular block, when the faces are flat and edges of the cubes are sharp, and subangular blocky, when the faces and edges are mainly rounded. The blocklike soil structures are mainly found in subsurface horizons.

Spherelike. All axes are developed equally with the same length, curved, and irregular faces. A spheroidal type of structure has two subtypes: granular, when the aggregates of this type are usually less porous, and crumb, when the granules are porous. Granular and crumb structures are mostly found in surface soils.

The soil structure of Bangladesh soils is of lesser importance inasmuch as most of the soils are alluvial and used for lowland rice culture where the puddling of soils makes the soils rather structureless.

6.3 Soil Color

Color is one of the most obvious characteristics of soil. Soil color is related to organic matter content, drainage condition, aeration of soil, and oxides of iron. The dark color of soil may be due to the presence of organic matter. Iron oxides may impart red to yellow color to soil. Soil color has no direct effect on plant growth but an indirect one through its effect on temperature and moisture. Soil color is an indicator of the climatic condition under which a soil was developed or of its parent material.

The three variables of hue, value, and chroma are used to describe color. Hue is the dominant spectral color and is related to the wavelength of light. Value refers to the relative lightness of color and is a function of the total amount of light. Chroma is the relative purity or strength of the spectral color. The color of the soil is matched with the Munsell color chart. In Munsell color charts, three basic hues are used: red (R), yellow red (YR), and yellow (Y), preceded by numbers 0–10. The notation for value consists of numbers from 0 for absolute black to 10 for absolute white. The notation for chroma consists of numbers beginning at 0 for neutral grays increasing at equal intervals to 8.

6.3.1 Significance of Soil Color

Soil color is probably the primary soil property for human perception. The darker color resulting from the presence of organic matter is a sign of higher productivity, whereas the

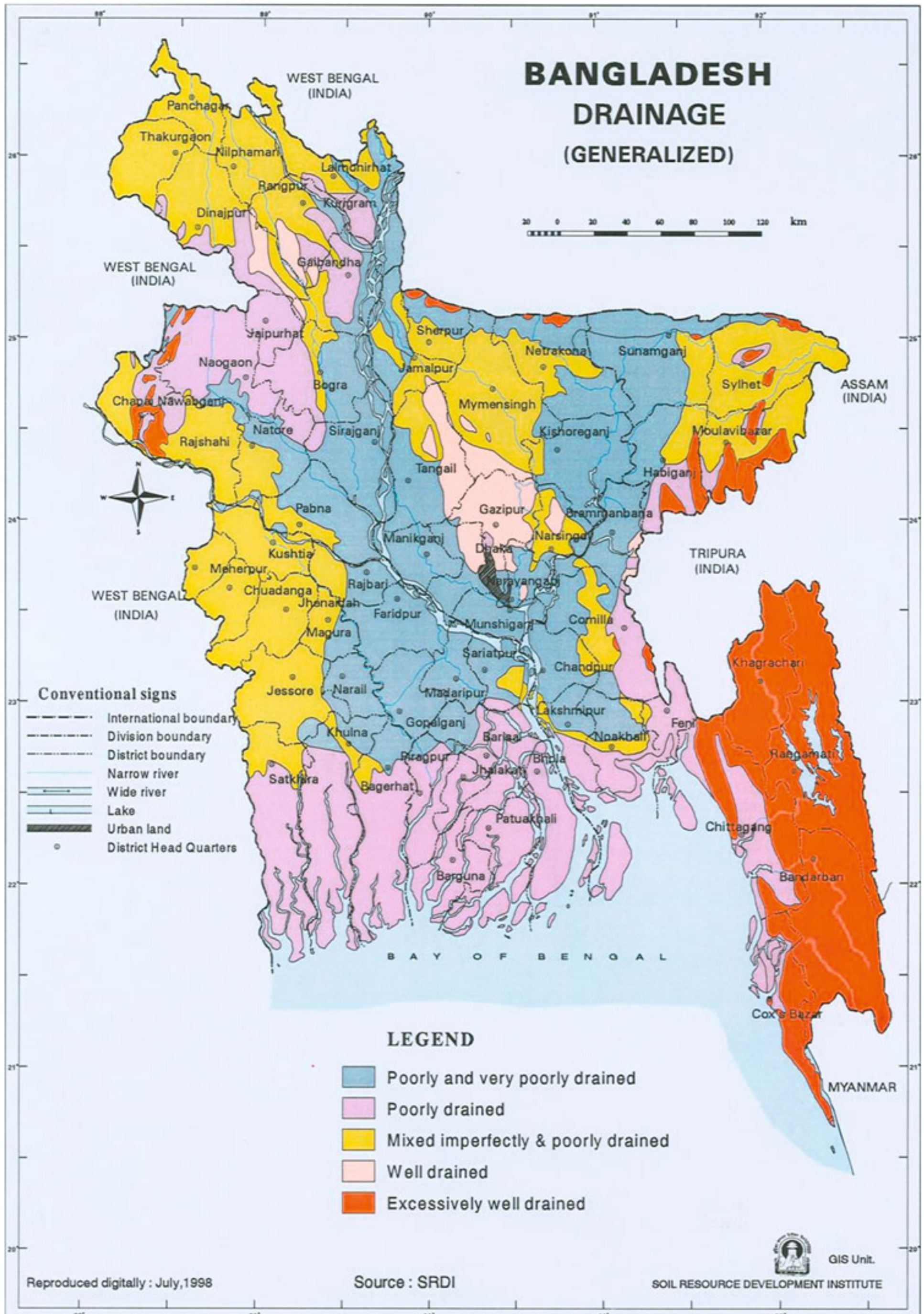


Fig. 6.2 The soil drainage pattern of Bangladesh (*Source* SRDI)

light color resulting from the preponderance of quartz has no nutritional value. The color is an indication of parent material in young soil. In mature soils, the color is an indication of the climate in which they have developed. A red color is an indication of good drainage. A light color is frequently the result of the removal of iron from the soil by leaching. The presence of mottles indicates the intermittent oxidation–reduction and presence of temporary excess water and lack of aeration.

Soil horizons differ in color. The difference in color is more obvious in mature soils and less so in young soils. The color of soil is used in the classification of soil. For example, the great soil groups: chernozem (black), sierozem (gray), podzol (ash-gray), latosol (red), and andosols (dark) were done on the basis of soil color.

Color variation of Bangladesh soils is not that prominent. The older soils of the Barind Tract, Madhupur clays, and hills have different hues of red; most other soils are different

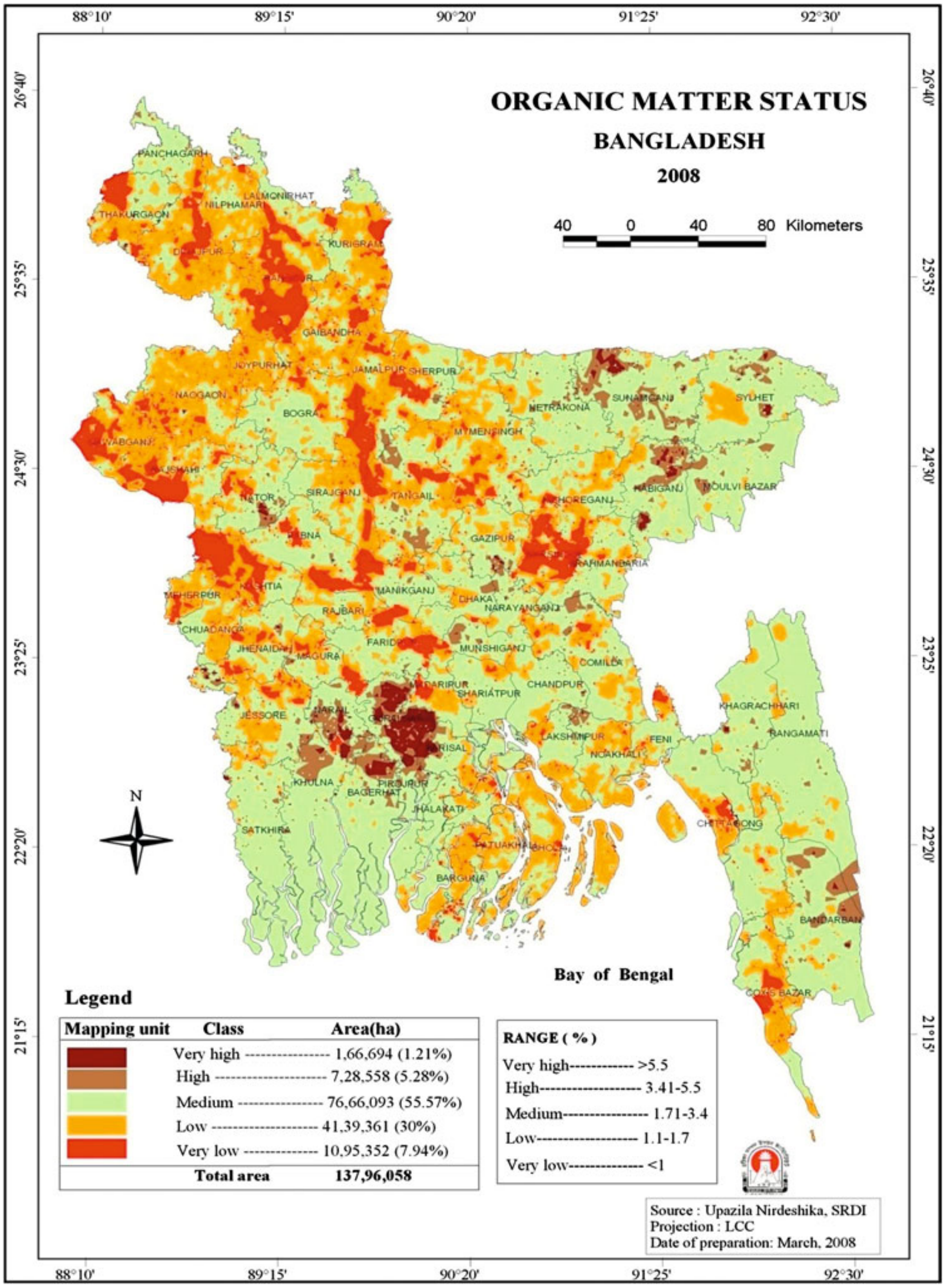


Fig. 6.3 The organic matter status of Bangladesh soils (*Source* SRDI)

shades of gray and the basin soils are darker in color. Soil color is given due importance during series identification and horizon differentiation.

6.4 Soil Density

Soil density is the weight per unit volume of the soil. It is expressed in gram per cubic centimeter, pound per cubic foot, or mega gram per cubic meter. Two types of density are commonly used for soil: bulk density and particle density.

6.4.1 Particle Density

Particle density is the mass (weight) per unit volume of the solid portion of soil. It is also termed "true density." It depends on the accumulative densities of the individual inorganic and organic constituents of the soil and is not affected by pore spaces. Although there is a considerable range in the density of the individual soil minerals, the values for most mineral soils usually vary between 2.60 and 2.75 Mg/m^3. The particle density is higher in soils containing such heavy minerals as magnetite, limonite, hematite, zircon,

and the like. Particle density decreases with increasing organic matter content.

6.4.2 Bulk Density

Bulk density is defined as the mass (weight) per unit volume of a dry soil. The volume includes both solids and pores. The bulk density of a soil is always smaller than particle density. Loose and compact soils have low weight per unit volume and compact soils have more weight per unit volume. Bulk density normally decreases as mineral soils become finer in texture. Generally in normal soils bulk density ranges from 1 to 1.65 Mg/m^3. Bulk density is of greater importance than particle density. Generally, soils having low bulk densities exhibit favorable conditions for plant growth.

No generalization could be made on the particle densities for Bangladesh soils. Alluvial soils have low bulk and particle densities compared to the older soils. The particle density of Bangladesh soils varies between 2.20 and 2.70 Mg/m^3 and the bulk density is from 1.20 to 1.35 Mg/m^3.

Soil texture, structure, porosity, particle density, and bulk density together determine the drainage of a soil. If we look into the soil drainage map of Bangladesh, it becomes clear that the soils of hills in the eastern part are well drained whereas most other soils are poorly to moderately drained (Fig. 6.2).

6.5 Soil Temperature

Soil temperature is one of the most important soil properties that affects plant growth along with other growth factors such as water, air, or nutrients. It affects plant growth directly and also influences soil structure, moisture, aeration, the activity of microorganisms, the decomposition of plant residues, and the availability of plant nutrients.

Soil temperature in Bangladesh has not been given much importance as far as crop cultivation is concerned. However, high atmospheric and soil temperatures during the summer are major concerns for rapid organic matter decomposition.

6.6 Soil Organic Matter

The organic matter status of Bangladesh soil is one of the poorest in the world. The average OM content of Bangladesh soils is less than 1 % ranging between 0.05 and 0.9 % in most cases. Soils of peat lands and some lowlying areas usually contain OM higher than 2 % on average. The OM supply in soil is one of the major constraints of the agriculture of the country. In general, the organic matter status of Bangladesh is characterized by very low to low to medium. The organic matter content of Bangladesh soil is very irregular (Fig. 6.3).

References

FAO-UNDP (1988) Land resources appraisal of Bangladesh for agricultural development. Report 2: agroecological regions of Bangladesh. Report prepared for the Government of the People's Republic of Bangladesh by the Food and Agriculture Organization of United Nations, United Nations Development Programme. BGD/81/035, Technical report 2, pp 1–570

7 Problem Soils

Problem soils can be defined as the soils on which most plants and crops cannot be grown economically and are not fertile or productive and there is the possibility of erosion hazard when cultivated. In other words, soils that are not suitable or fit for crop production are called problem soils, those soils possessing a severe limitation of certain physical or chemical characteristics, either inherent or artificial, on successful crop production. In general, these soils have the lowest priority for agricultural uses (Rahman 1991).
The extent of problem soils in the country is substantial. These include soils with high acidity, highly saline soils, soils with high erodibility, and soils in the depressions. Soils with very low organic matter content are also considered problem soils. These soils need special soil–water–fertilizer–crop management practices to make them productive.

The different types of problem soils encountered in Bangladesh are summarized in Table 7.1. The map in Fig. 7.1 shows the distribution and extent of the different problem soils that occur in Bangladesh.

7.1 Saline Soils

Earlier, of the 2.85 million hectares of coastal area of Bangladesh about 0.833 million hectares were recognized as saline soils (Karim et al. 1990). The salinity problem did not receive enough attention in the past, but now much emphasis has been given to this issue. In the recent past observations it was noticed that due to an increasing degree of salinity of some areas and expansion of the salt-affected area as a cause of further intrusion of saline water, normal crop production becomes more restricted. In general, soil salinity is believed to be mainly responsible for low cropping intensity in this area. It was strongly and reasonably felt that mapping of the present coastal saline area on a smaller scale with the help of modern tools such as remote sensing and GIS would be necessary including characterization of the coastal saline soil resources through further investigation. This led to the special reconnaissance survey conducted by SRDI of the coastal area of Bangladesh in 2000 (SRDI 2003). The degree and extent of salinity is increasing. The saline area in the country is now estimated to be 1.06 million hectares out of the 1.459 million hectares of cultivated land. This increase of salinity is considered to be a resultant effect of the present global climate change. In the coastal regions of Bangladesh, the saline areas vary from place to place due to variation in the fluctuation of groundwater and seasonal variation. The salinity of Bangladesh soils is coastal salinity and the extent increases with dryness and falls with the advent of the rainy season. The salinity starts augmenting from the end of November and attains its peak during the months of May and June and then it starts declining. The extent and location of coastal saline soils in Bangladesh as of 1973 are shown in Table 7.2.

During high tide, seawater flashes alluvium, causing saline water intrusion on the mainland and the deposition of salts. Soil salinity is the lowest in the northwest and gradually increases towards the west. The highly silty estuarine floodplains are more saline. The Sundarbans' soils are moderately saline to saline in the east and highly saline in the west. The factors involved in the salinization are land relief, degree of flooding, the nature of the soil, precipitation, tidal action, the effect of the river system and its discharges, depth of the groundwater table and salt deposits, the slope of the ground, and the proximity to drainage channels. Maximum salinity occurs in the months of March to June due to low precipitation and high evaporation and minimum salinity occurs in the months of July and August due to high precipitation and low evaporation. Seawater inundation caused by cyclonic storms makes coastal areas saline by impregnating the soils with soluble salts. The maps shown in Figs. 7.2, 7.3, 7.4 show the changes in the salinity pattern of the country during 1973, 2000, and 2009. There has been a rapid change in the salinity regime in the coastal area over a very short period.

The distribution in terms of extent of salinity is shown in Table 7.3.

S. M. I. Huq and J. U. M. Shoaib, *The Soils of Bangladesh*, World Soils Book Series 1,
DOI: 10.1007/978-94-007-1128-0_7, © Springer Science+Business Media Dordrecht 2013

Table 7.1 Summary of the problem soils of Bangladesh

Nature of soils	Area (mha)
Saline soil	0.83
Acid sulfate soil	0.23
Peat	0.13
Organic matter deficit soil	5.00
Sulfur deficit soil	4.95
Zinc deficit soil	1.74
Coarse textured soil	0.44
Soils with dominant pan	2.30
Drought-prone soils	5.73
Alluvium/young soils with risk of bank erosion/burial of fresh sediment	1.20
Very deeply flooded/very poorly drained soils	0.35
Hilly soils with risk of erosion	1.73
Total:	24.63

Source SRDI 1965–1986

Coastal saline soils occur in the river deltas in a strip of land a few km to 180 km wide along the seacoast. The landscapes are lowlying land, estuaries, and inland along the coast of Bangladesh. A reduction in the upstream flow of the Ganges water has increased salinity in the tidal river, decreased surface water availability in the rivers and canals, lowered the groundwater table, and reduced soil moisture content. The increase of water salinity of these areas has created a suitable habitat for shrimp cultivation. Along with other factors shrimp cultivation has played a major role in the increase of soil salinity particularly in the southwestern coastal areas. About two decades ago paddy cum brackish water shrimp cultivation practice was introduced in high-salinity areas of Bangladesh. About 1,360 hectares of land are occupied by shrimp cultivation in these areas (SRDI 2003). In the Greater Khulna district about 31,200 hectares of land in 1982–1983 and about 98,850 hectares of land in 1993–1994 were brought under shrimp cultivation.

Sodic soils occur in very small parts of Bangladesh mainly in some tidal areas but they have not been identified with certainty. They occur along with the saline soils together with the salt-affected soils. Sometimes located in small areas called "*slick spots*," sodic soils may be surrounded by soils that are considerably more productive. Sodic soils usually have very thin A horizons overlying a clayey layer with columnar structure. The small patches of alkali soils that occur on some floodplain ridges in the west of the Ganges River floodplain did not form under conditions of tidal flooding (Brammer 1996). The total area of sodic soil in Bangladesh is estimated to be about 538,000 hectares (SRDI 2003).

7.2 Acid Sulphate Soils

Acid sulfate soils are soils that contain iron sulfides and commonly occur in coastal lowlands, estuaries, floodplains, wetlands, and mangrove environments. When exposed to aerobic conditions through proper drainage, these soils produce sulfuric acid. Acid sulphate soil is one of the major problem soils in Bangladesh covering an area of about 0.23 million hectares and occurring mainly in the south-eastern and southwestern zones. Among the different problem soils in the coastal areas of Bangladesh, only acid sulfate soils could display a high agricultural potential if they were to be reclaimed by appropriate methods (Khan et al. 1994).

Hussain (1992) and Shaheed (1984) have estimated that 2,266 km^2 of the total land area of 1,44,862 km^2 in Bangladesh is acid sulfate soil, which is branded as problem soil in Bangladesh. Acid sulfate soils were first recognized in the coastal areas of Bangladesh. These soils are locally known as *Kosh* in Chittagong because of their combined saline and acidic character. The name Kosh was originally given by the local people of the Chittagong coastal belt perhaps due to the astringent tastes of the soil solution. Acid sulfate soils in Bangladesh occur extensively in Chakoria, Sundarbans, Teknaf, and Maheshkhali upazilas of Cox's Bazar district, Shamnagar and Dacope upazilas of Khulna, and Morelgonj upazila of Bagerhat district. In addition to these, acid sulfate soils also occur in small areas of Bashkhali, Kutubdia, Ruma, Ukhiya, and Sadar upazilas of Cox's Bazar district; Debhatta, Kaligonj, Satkhira, and Tala upazilas of Khulna and Sadar, and Rampal and Kaucha upazilas of the Bagerhat district. These soils occur in the basin southwest of the Ganges tidal floodplain in Satkhira, more extensively on young tidal floodplains, and in Chakoria of Cox's Bazar on the Chittagong coastal plain. The rise in sea level causes inundation of land. They are thionic fluvisols and have either a sulphidic layer between 50 and 125 cm or a sulphuric horizon (pH < 3.5) in any part of the profile between the surface and 125 cm.

7.3 Acidic Basin Clays

Acidic basin clays occupy an area of around 3,490 km^2. These soils occur in several places within the floodplain areas. They typically occur on the haor areas of Sylhet and Mymensingh distrcits, the lower Atrai basin, Arial beel, the

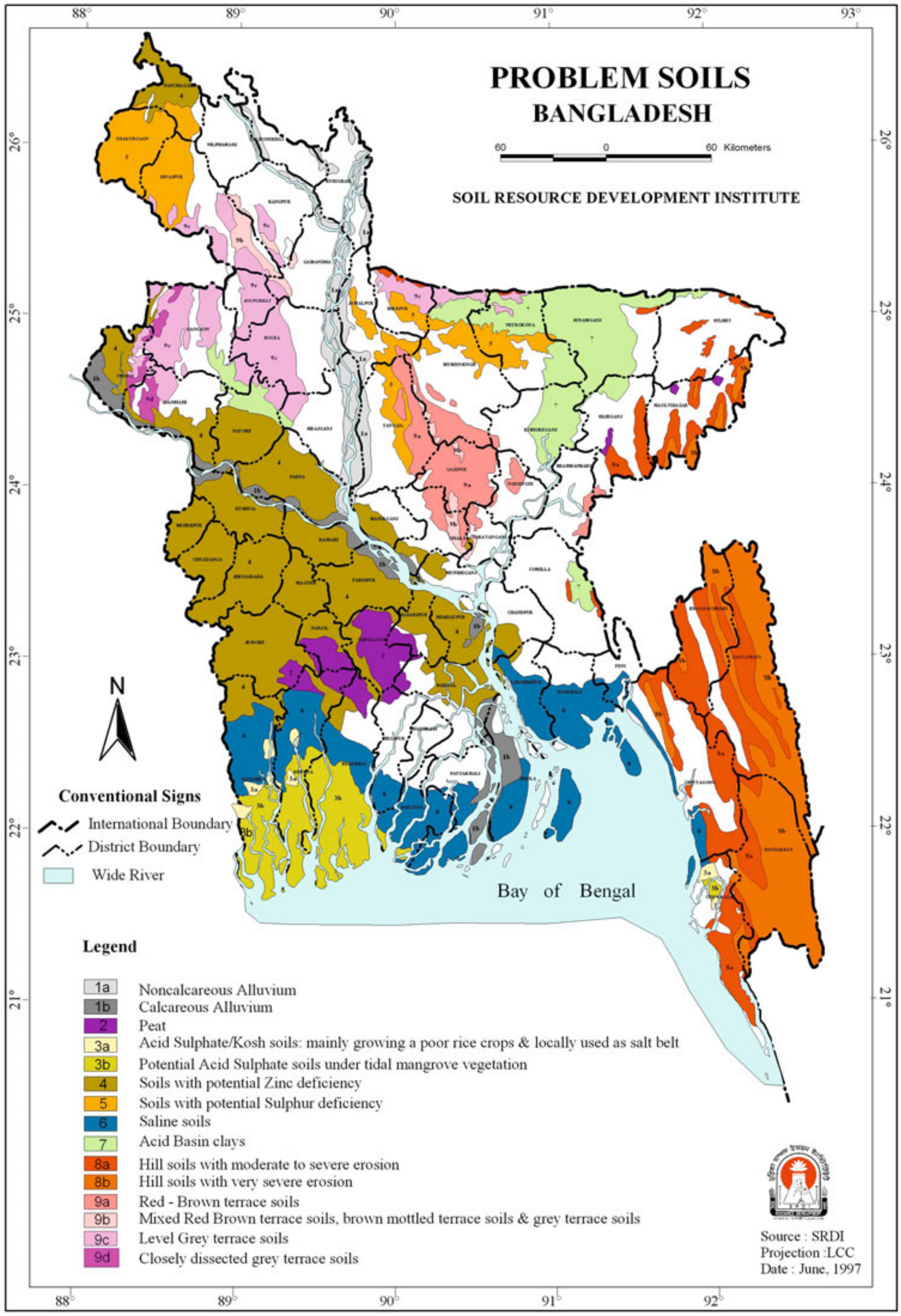


Fig. 7.1 The problem soils of Bangladesh (*Source* SRDI)

Comilla basin, and in some broad valleys within the Madhupur and Barind Tracts. They are heavy-textured soils, and are strongly acidic when dry and near neutral when wet. The topsoil color is grey to dark grey and has numerous red and yellow mottles along the root channels. Because of plowing, the top soil is sometimes compacted. These soils develop large polygonal blocks when dry. The subsoils are grey to dark-grey heavy clays and have strong yellow to red mottles. Their structure is coarse prismatic to blocky. Some structural units have shiny pressure faces. The subsoil is usually strongly to extremely acidic in reaction. The agricultural potential of these soils is limited by the moderately deep to very deep seasonal flooding (Hussain 1992).

Severe limitations for agricultural production are provided by:

- The prevalent heavy clay soils
- Deep and open rapid flooding
- Drought in the premonsoon season

Table 7.2 Extent and location of the saline soils

District	Area (000 ha)
Satkhira	146.35
Khulna	120.04
Bagerhat	107.98
Barguna	103.55
Patuakhali	115.10
Cox's Bazar	54.70
Noakhali	49.60
Chittagong	45.70
Bhola	40.33
Pirojpur	20.30
Laxmipur	19.30
Feni	9.00
Chandpur	1.50
Grand total	833.45

- The relatively long cold winter
- Extremely high summer temperatures (Brammer 1996).

7.4 Sulphur- and Zinc-Deficient Soils

Sulphur-deficient soils rank third of the problem soils identified in Bangladesh. The deficiency of sulphur is prominent in light-textured soils. About 3.95 million hectares of land are sulphur deficient (Fig. 7.5), which represents approximately 16 % of the total problem soils in Bangladesh. These soils need sulphur fertilization for optimum yield of crops. Gypsum, elemental sulphur, or zinc sulphate are the sources of fertilizer used.

Zinc-deficient soils occupy 1.75 million hectares among the different problem soils (Fig. 7.6). Although zinc deficiency occurs locally, it may be widespread in the calcareous soils (pH > 7.5) with moderate to high organic matter content, peat soils, saline soils, and light-textured piedmont soils.

These deficiencies are caused because of increased use of high analysis sulphur- and zinc-free fertilizers such as urea, TSP, minimum application of micronutrients, increased crop yield through cultivation of modern high-yielding variety crops, and continuous wetting of the soil. Zinc- and sulphur-deficiency problems can be reduced through the application of zinc- and sulphur-containing fertilizers.

7.5 Soils with Dominant Pan

Bangladesh is one of the most important rice-growing countries in the world. Plowpan formation is a common problem in most of the wetland rice growing areas in Bangladesh. A compact layer of 3–5 cm is formed 10–12 cm below the surface due to puddling year after year. Plowpan is found in most soils, specifically in silt loam soils, which are cultivated in a wet condition and are puddled for transplanted rice cultivation. Soils with plowpan occupy about 2.30 million hectares in the Tista, Ganges, Brahmaputra, and Meghna floodplains and Barind areas. Plowpan is disadvantageous for deep-rooted upland crops. Deep plowing can be used to break down plowpan for cultivation of upland crops. In addition, plowpan formation can be impeded by cultivating rice and upland crops in the same field in rotation using deep plowing equipment. Studies on soil bulk density and penetrometer tests confirmed the presence of plowpans in the soils. Loss of bearing capacity of some soils may occur after destroying the plowpan by deep mechanized plowing. Usually, the plowpan is associated with soils such as silt loams and silty clay loams due to their poor structural stability. Although the plowpan is beneficial in maintaining standing water in transplanted rice fields, it is detrimental to root penetration and absorption of moisture by some rabi crops from deeper layers.

7.6 Drought-Prone Soils

Droughts are a common feature in most parts of Bangladesh. The northwestern and northeastern parts of Bangladesh are becoming dry because of obstruction of the normal flow of water in different rivers. This normal flow of water is being hampered because of restricted water flow from upstream of the main rivers flowing from the neighboring country due to construction of dams and barrages. These artificial structures divert the flow of water during the dry season creating a scarcity of surface water in the northwestern and northeastern parts of Bangladesh. The northwestern districts of Rajshahi, Dinajpur, Rangpur, Bogra, and Pabna are particularly drought-prone. These areas receive only 127 cm of rainfall annually. Approximately 5.73 million hectares of Bangladesh land are plagued by moderate and/or severe drought. Drought-prone areas of Bangladesh are based on drought intensity for Kharif (Table 7.4 and Fig. 7.7) and Rabi crops (Table 7.5 and Fig. 7.8).

7.7 Peat Soils

Peat soils are those soils that contain more than 20 % organic matter. Peat soils occupy about 0.13 million hectares, representing approximately 0.9 % of the total problem soils of Bangladesh (Table 7.6). These soils occur in low-lying areas of the Gopalganj–Khulna beels, deep

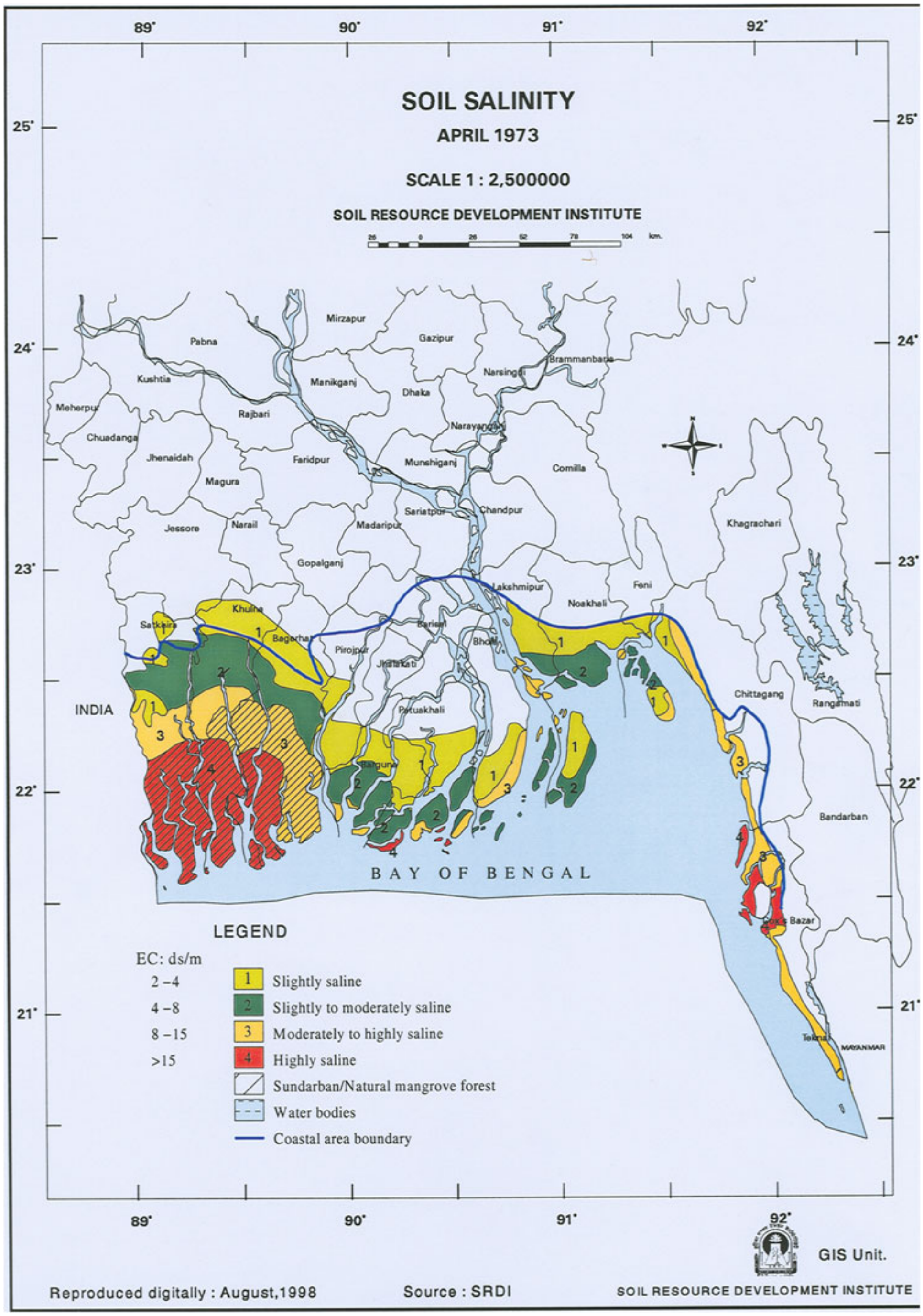


Fig. 7.2 The extent of saline areas mapped in 1973 (*Source* SRDI)

depressions in the Sylhet basin, and in the northern and eastern hills. The distribution and amount of peat soils in Bangladesh are given in the table. The bulk density of peat surface soil is only 0.20–0.30 gm/cm^3. The soils have low bearing capacity when wet, strong acidity, low nutrient status, and perennial wetness; these are the main constraints for crop production. Organic matter in these soils occupies more than half of the upper 80 cm of the profile. In the upper peat basin, the soils consist of alternating layers of organic matter and are at various stages of decomposition (FAO-UNDP 1988). Most peat in Bangladesh is derived from reeds and grasses which are the major vegetation of marshy lands. Peat soils are regarded as a kind of problem soil in Bangladesh, and are not properly used (Hussain 1992). Where there is a mineral topsoil above the peat, rice cultivation is practiced. When peat occurs at the surface it usually remains under swamp grassland. The agricultural potential of Bangladesh's peat soils is generally low. This is

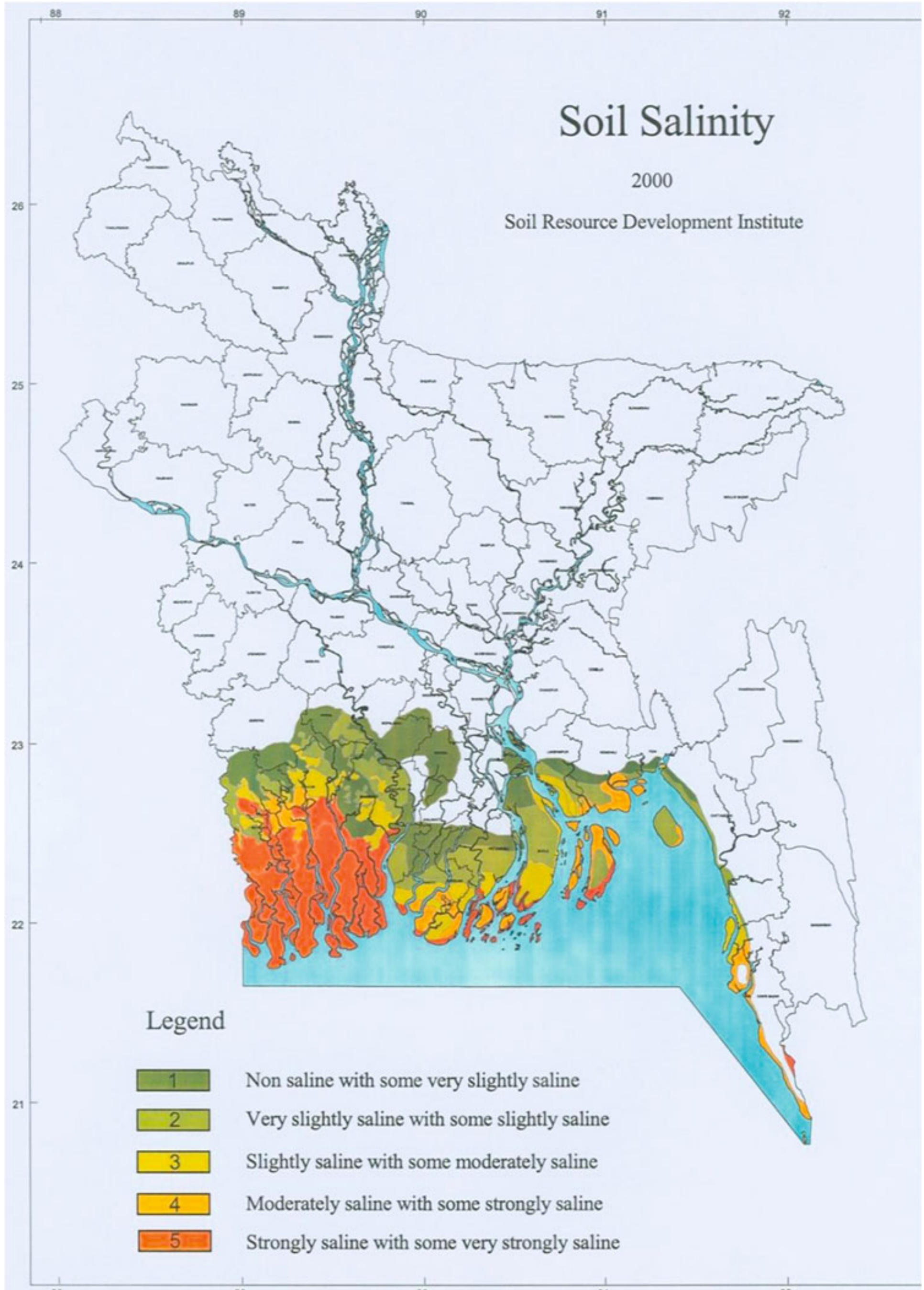
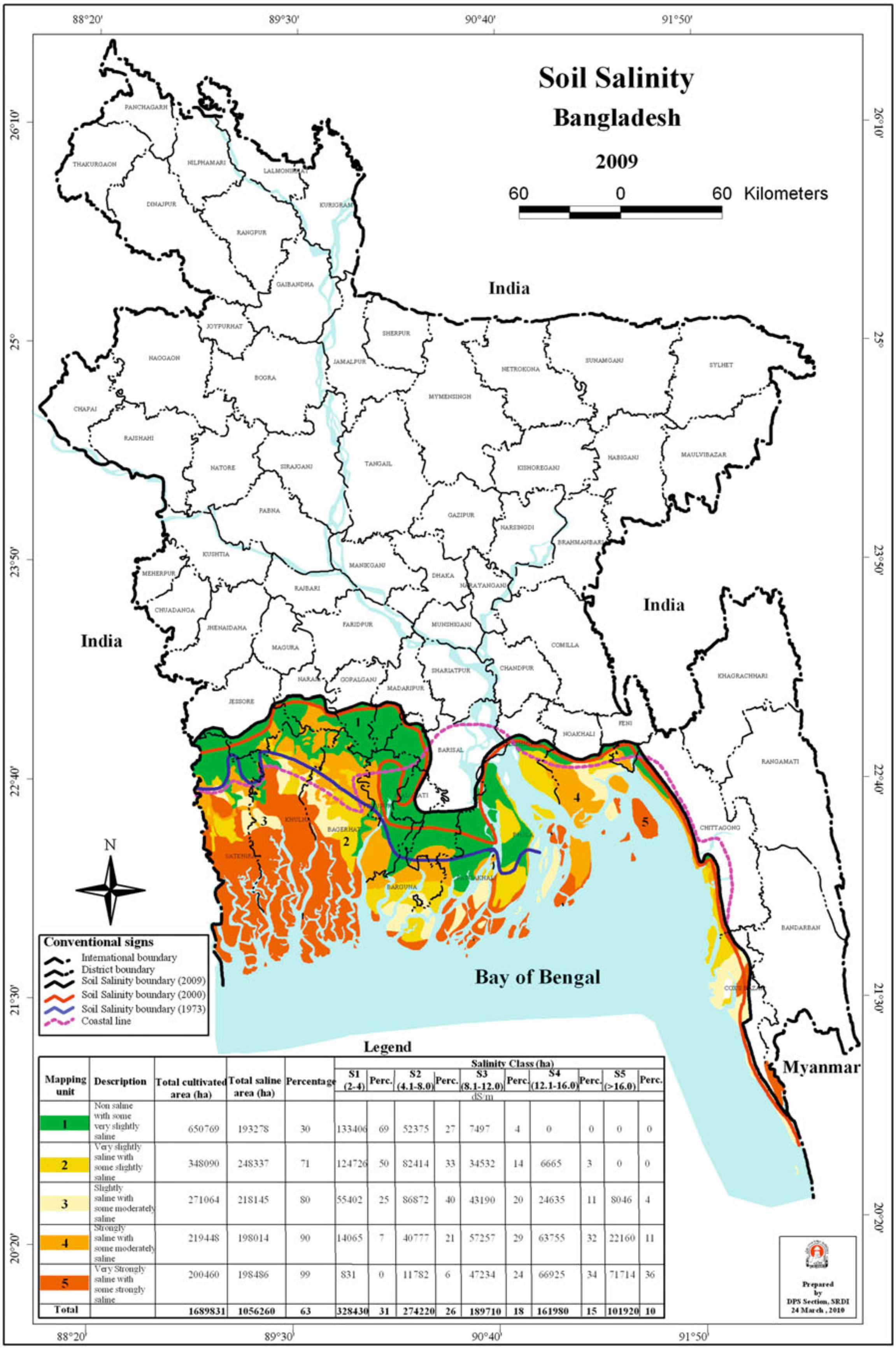


Fig. 7.3 The extent of saline soils mapped in 2000 (*Source* SRDI

because of their deep flooding during the wet season and poor transport facilities.

7.8 Organic Material-Deficit Soils

In Bangladesh, organic carbon distribution in the floodplain soil is rather irregular. In terrace and hill soil, the organic carbon content decreases regularly with depth but does not usually reach a level of 0.2 % or less. More than half of the agricultural lands contain <1.5 % organic matter (Fig. 7.9). There are several reasons for the low content of organic matter in Bangladesh. High temperature and adequate moisture are suitable for rapid decomposition of organic matter. In addition, high cropping intensity, removal of plant residues, and very little addition of organic manure are responsible for the low level of organic matter. The increasing intensity of land use for producing more food grains results in severe exhaustion of organic matter from the soil. The high population growth demands for increased crop



Legend

Mapping unit	Description	Total cultivated area (ha)	Total saline area (ha)	Percentage	Salinity Class (ha) dS/m S1 (2-4)	Perc.	S2 (4.1-8.0)	Perc.	S3 (8.1-12.0)	Perc.	S4 (12.1-16.0)	Perc.	S5 (>16.0)	Perc.
1	Non saline with some very slightly saline	650769	193278	30	133406	69	52375	27	7497	4	0	0	0	0
2	Very slightly saline with some slightly saline	348090	248337	71	124726	50	82414	33	34532	14	6665	3	0	0
3	Slightly saline with some moderately saline	271064	218145	80	55402	25	86872	40	43190	20	24635	11	8046	4
4	Strongly saline with some moderately saline	219448	198014	90	14065	7	40777	21	57257	29	63755	32	22160	11
5	Very Strongly saline with some strongly saline	200460	198486	99	831	0	11782	6	47234	24	66925	34	71714	36
Total		**1689831**	**1056260**	**63**	**328430**	**31**	**274220**	**26**	**189710**	**18**	**161980**	**15**	**101920**	**10**

Fig. 7.4 The extent of saline soils mapped in 2009 (*Source* SRDI). *Note* Figures in parentheses indicate percentage of total saline area

Table 7.3 The extent of salinity in terms of salinity category

Total cultivated area (ha)	Total saline area (ha)	S1 (2–4 dS/m)	S2(4.1–8.0 ds/m)	S3 (8.1–12.0 dS/m)	S4 (12.1–16.0 dS/m)	S5 (>16.0 dS/m)
1,689,831	1,056,260	328,430 (31)	274,220 (26)	189,710 (18)	161,980 (15)	101,920 (10)

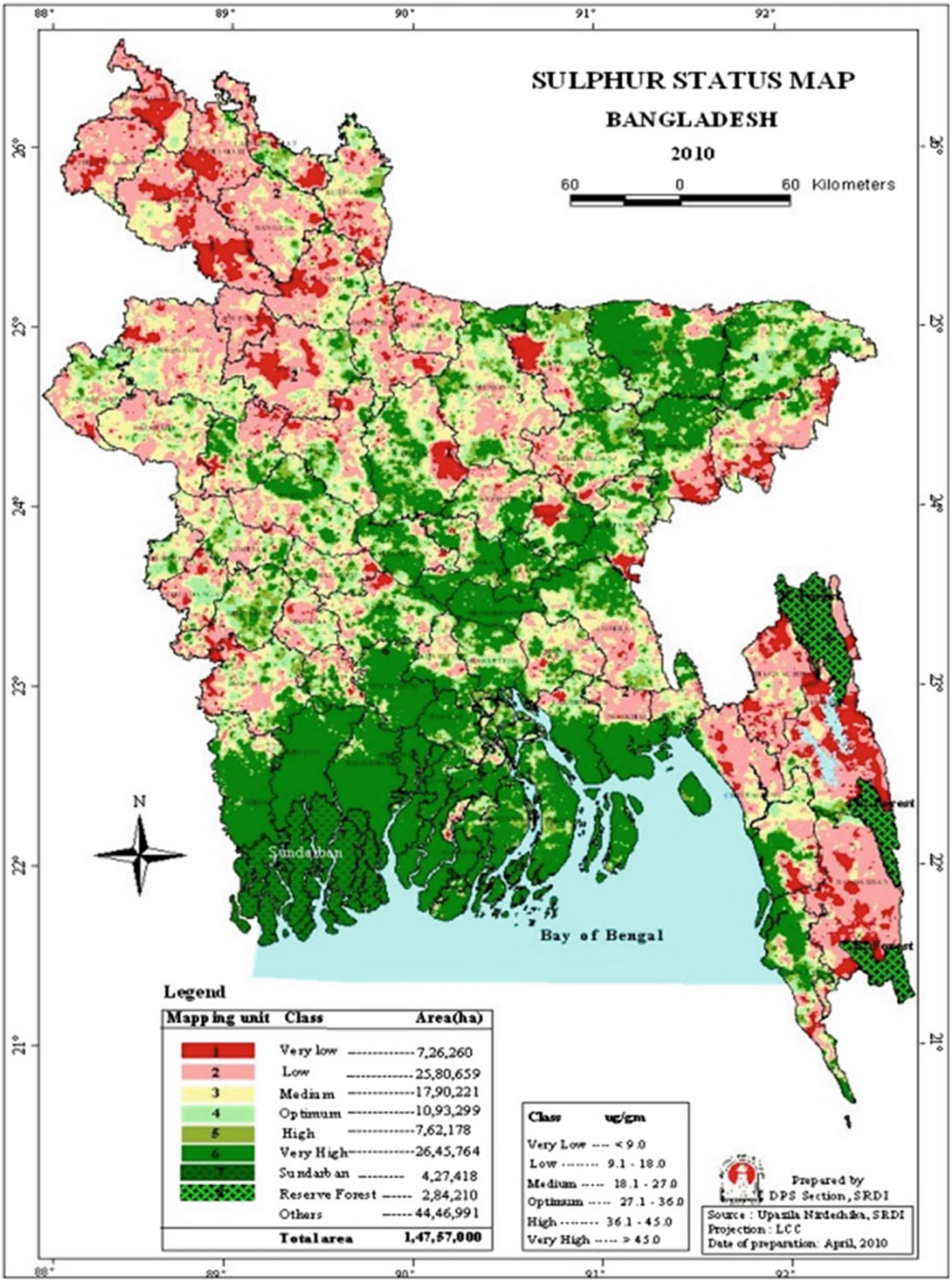


Fig. 7.5 Sulfur-deficient soils of Bangladesh (*Source* SRDI)

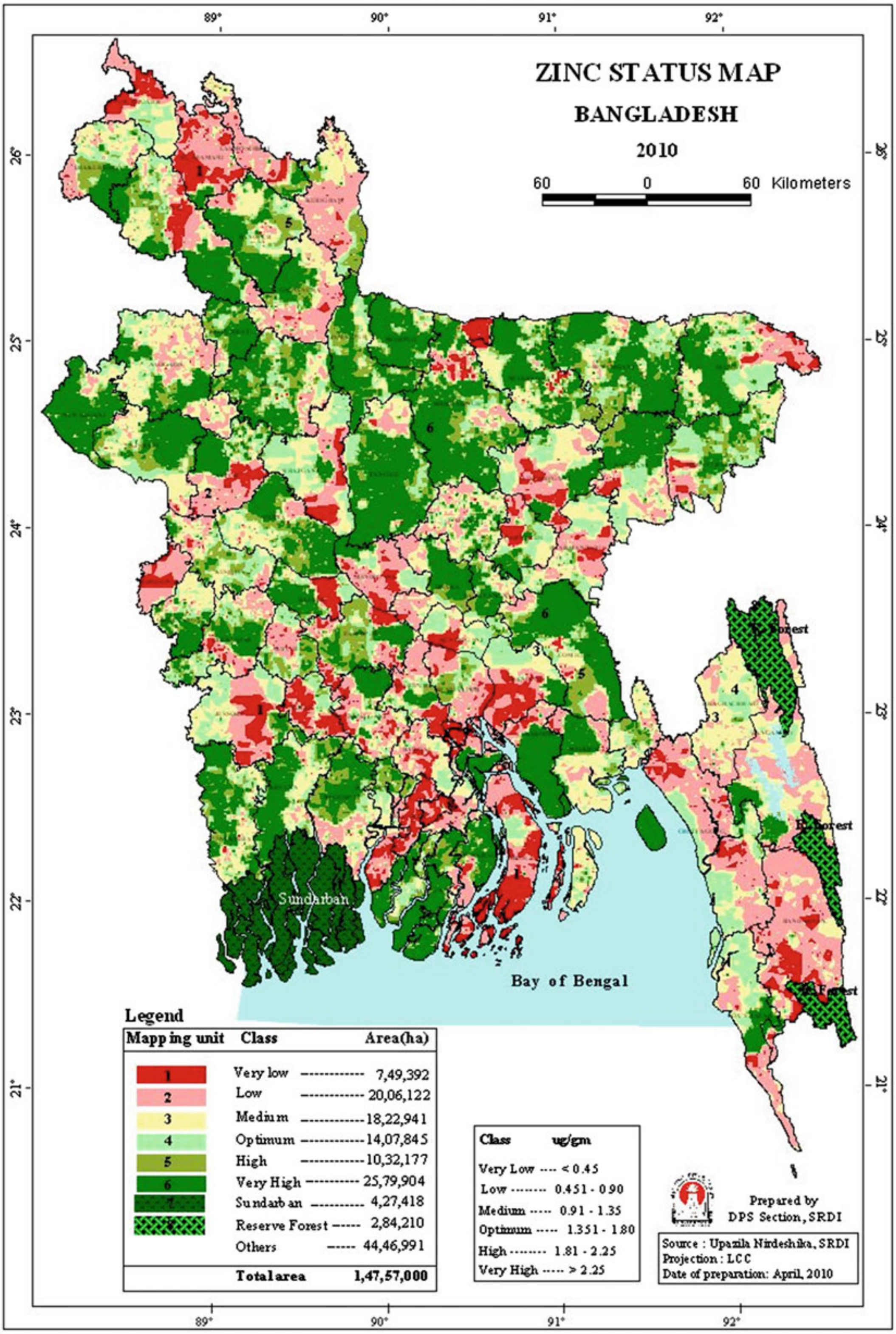


Fig. 7.6 Zn-deficient areas of Bangladesh (*Source* SRDI)

Table 7.4 Drought-prone areas of Bangladesh based on drought intensity for Kharif crops

Drought intensity	Drought-prone areas
Very severe	Rajshahi and Chapai Nawabgonj district
Severe	Dinajpur, Bogra, Kustia, Jessore, and part of the Dhaka and Tangail districts
Moderate	Rangpur and Barisal districts and some parts of Dinajpur, Kustia, Jessore, and part
Low	Tista, Brahmaputra–Meghna floodplain areas

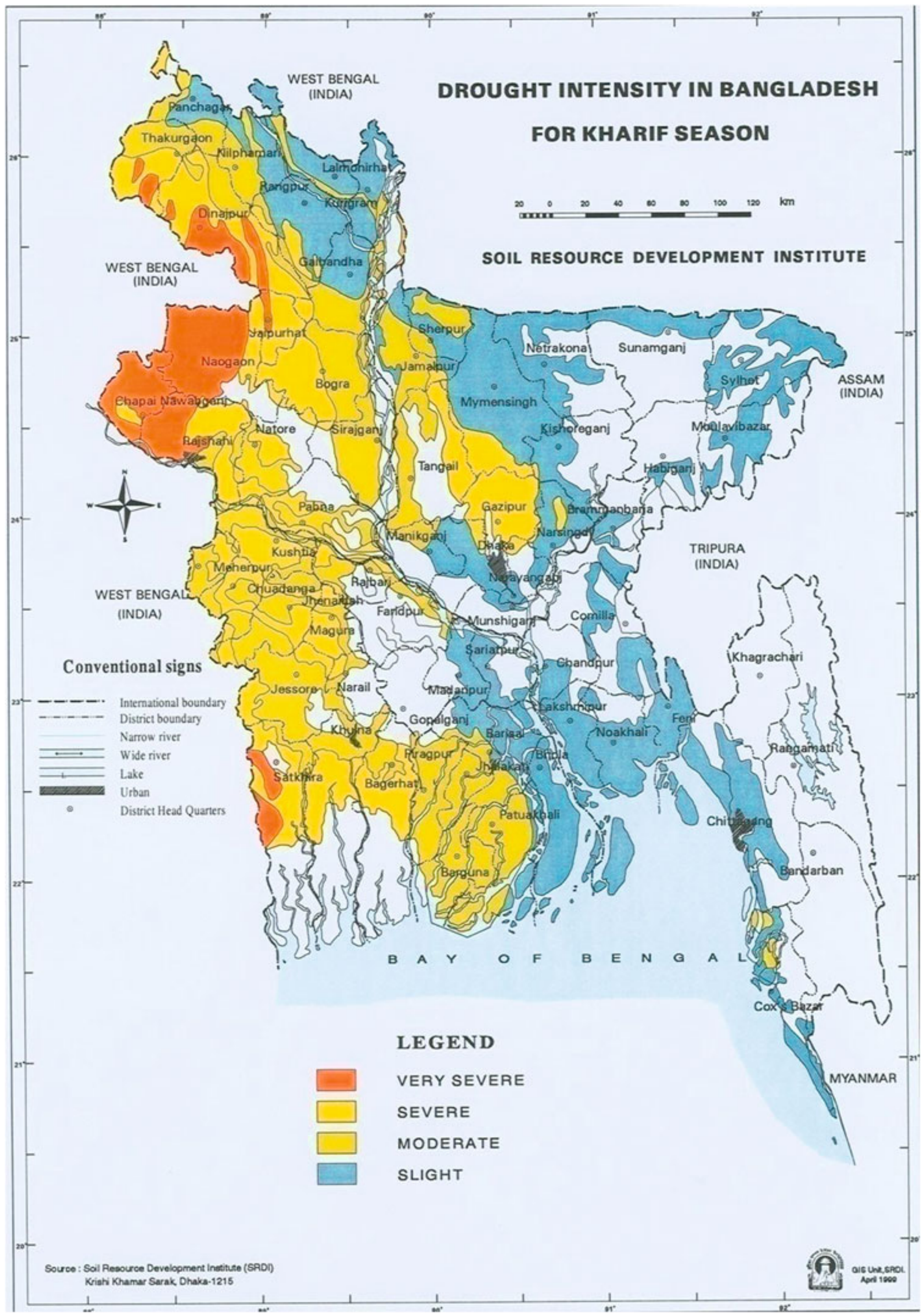


Fig. 7.7 Drought-prone areas of Bangladesh during Kharif season (*Source* SRDI)

Table 7.5 Drought-prone areas of Bangladesh based on drought intensity for Rabi crops

Drought intensity	Drought-prone areas
Very severe	Rajshahi, Naogaon, and Chapai Nawabganj
Severe	Major parts of Barind and Ganges floodplain areas
Moderate	Major parts of Modhupur, Barind, and Ganges floodplain areas
Moderately low	Tista and Brahmaputra Ganges floodplain areas
Low	Surma-Kushiara, Tista, and Brahmaputra–Meghna floodplain areas
Very low	Sylhet, Gopalganj, and Khulna

production results in crop rotation with green manuring crops and use of farmyard manure. The high Ganges River floodplain, Old Meghna estuarine floodplain, and northern and eastern hills are subjected to a very low level of organic matter content. It is a common observation that organic carbon content in Bangladesh soil increases from the younger to the older sediments under similar land use conditions. In terrace and hill soils, organic carbon content decreases regularly with depth indicating the evidence of *in situ* mineralization of organic matter in well-drained upland soils. Organic matter in these soils decreases abruptly in the topsoil after the clearing of forests for cultivation. The decline is regular in the subsoil that remains unchanged below 100 cm. This indicates a higher rate of litter addition and mineralization in the topsoil especially under the forest vegetation. In Bangladesh forests, organic carbon content remains in equilibrium with the slope, aspect, vegetation, and texture. Organic matter content in soil declines steeply during the first 2–3 years after the equilibrium is disturbed by deforestation.

7.9 Deeply Flooded Soils

Deeply flooded areas which include haor, baor, beel, and jheel are poorly drained. In these areas soils become devoid of oxygen, with the consequent evolution of other gases such as carbon dioxide, methane, and nitrogen, which adversely affect upland crop production. Beels are large water bodies found in the active floodplains of the Surma–Meghna, the Brahmaputra–Jamuna, and the Ganges–Padma River systems. Some of the common beels are *Chalan beel*, *Gopalganj–Khulna beel,* and *Arial beel*. Beels remain deeply flooded during most of the wet season and dry in winter. In Bangladesh, haors are found mainly in greater Sylhet and greater Mymensingh districts. Baors are important wetlands of Bangladesh that support a wide range of aquatic life. Jheels are commonly found in the southwestern Ganges deltaic parts of the country.

7.10 Terrace Soils

Sparsely and deeply dissected terrace soils have high permeability, face drought in the dry season, and have low fertility with problems of phosphate fixation and sulphur deficiency that provide limitations on agricultural development (Huq 1984). Terrace soil consists of shallow red-brown terrace soils; they occupy an area of around 725 km^2 under the Gazari forest. Deep red-brown terrace soils occupy an area of 1894 km^2 in Madhupur in the center tract and Akhaura terrace in the east. Brown mottled terrace soils occur over an area of only 342 km^2 and are found on the imperfectly drained level sites of the Madhupur and Barind Tracts. The shallow grey terrace soils occupy an area of 2,654 km^2 and occur extensively on the level and high Barind Tracts and also in some areas of the Madhupur Tract. Deep grey terrace soils occupy a 3,522 km^2 area and occur extensively in the northwestern Barind Tract and the Madhupur Tract (Hussain 1992).

7.11 Steeply Sloping Soils

Steeply sloping soils occur widely in the hill areas of the Bandarban, Rangamati, and Khagrachhari districts. Hill areas constitute about 12 % of the country. Land degradation in hilly areas is one of the major problems in Bangladesh. Due to hill-cutting, landslides occur extensively every year and these landslides become more devastating during the heavy monsoon period. The clearing of natural vegetation for the cultivation of pineapple, ginger, and turmeric along the slopes has an adverse effect on soil erosion in Sylhet, Moulavibazar, and in the hilly areas of Chittagong. Cultivation along the slopes erodes the top fertile soils resulting in the loss of a huge amount of nutrient elements. Steep to very steep slopes, shallowness of the soil profile, severe possibility of drought in the dry season, moderate to rapid permeability, and susceptibility to serious erosion of hilly areas pose problems to crop cultivation. The erosion of soils in hilly areas can be reduced by increasing organic matter, cultivation of cover crops wherever possible, and leaving the soil surface barren as little as possible.

7.12 Alluvium/Young Soils

They occur within and alongside the Teesta, Brahmaputra, and Jamuna Rivers and parts of the Little Jamuna and Atrai floodplains. Young soil includes river chars and young floodplain land adjoining the river. The boundaries with other units are transitional and are subject to change with continuing river erosion and new alluvial deposition. The

Fig. 7.8 Drought-prone areas of Bangladesh during Rabi season (*Source* SRDI)

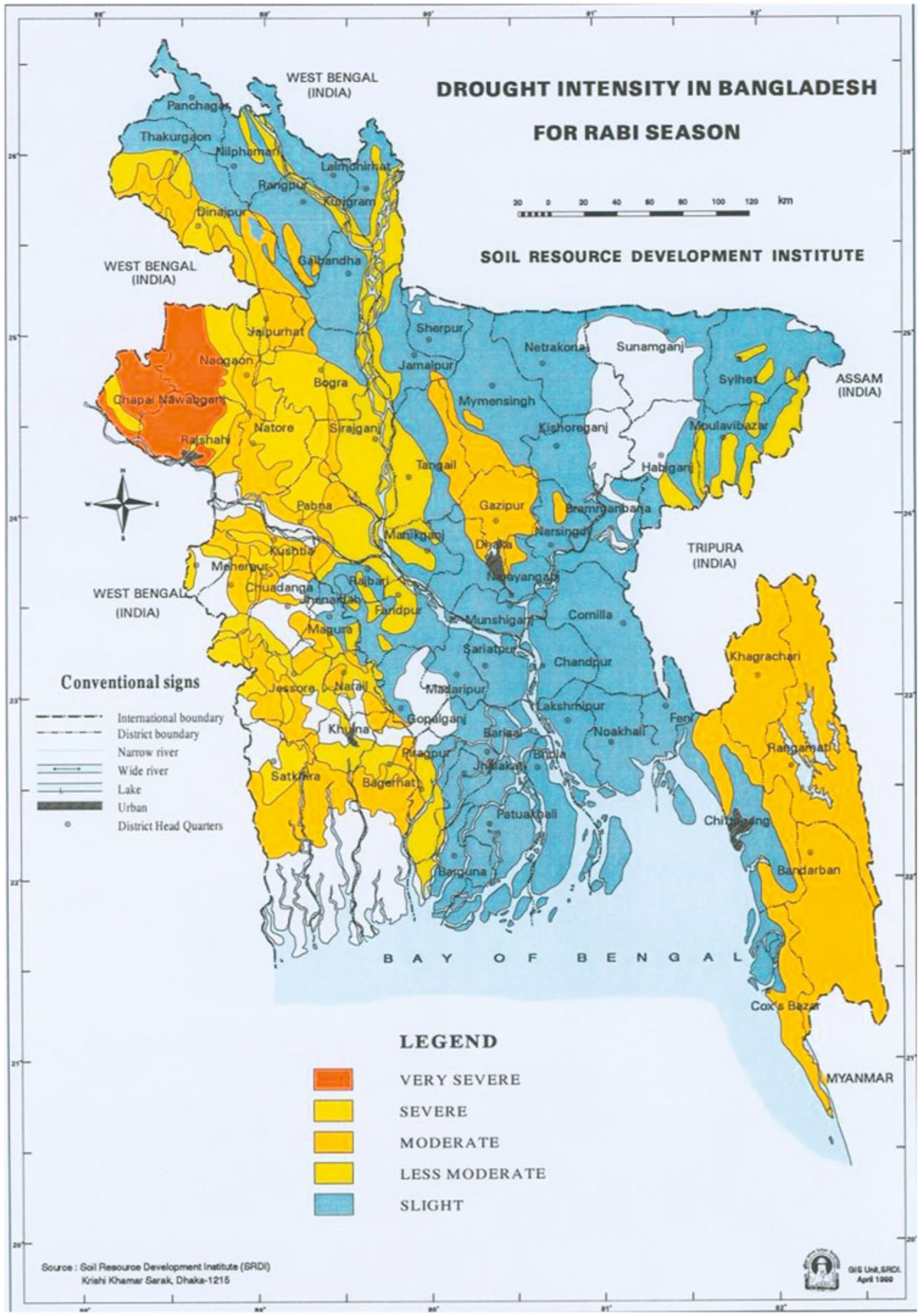


Table 7.6 The distribution and amount of peat soils in Bangladesh

Districts	Location	Area (m ha)
Madaripur	Baghia–Chanda beel	0.05
Khulna	Khulna Sadar, Kola Mauza Terokhada, Mollarhat	0.025
Moulavibazar	Chatal beel	0.0138
Sunamganj	Chatak, Pagla	0.0127
Total		0.13

relief is slightly irregular, with complex patterns of ridges and depressions, and river channels occupy about one third of the area (in the dry season). Rivers occupy nearly 30 % of the gross area. Silty soils predominate, but sands occur on some ridges and clays in some depressions. The proportions of silty and sandy alluvium are subject to change each flood season. Seasonal flooding is mainly shallow, but depressions are moderately deeply flooded, and the whole of the land area can be deeply flooded in years with high river floods.

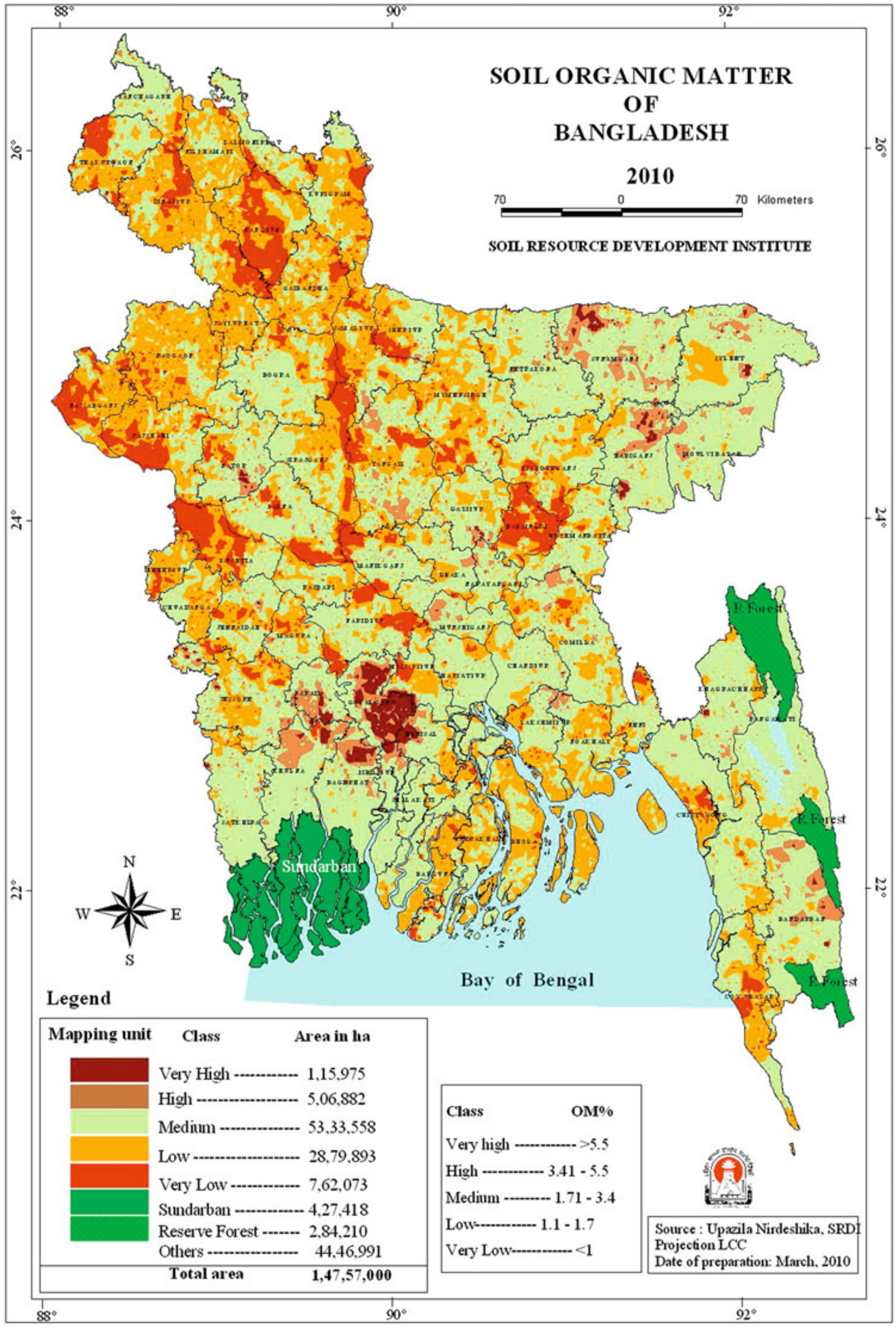


Fig. 7.9 The organic matter distribution of Bangladesh soils (*Source* SRDI)

Some areas of sandy and new silty alluvium remain bare or under grasses, but the greater part is cultivated, especially for dry-season pulses, mustard, and groundnuts. Jute or mixed aus and deepwater aman are grown in the Kharif season in areas where the hazard of early flooding is not too great. The hazard of riverbank erosion, burial by raw alluvium, rapid flow of floodwater, and periodic deep floods restrict the potential for investment in improved agricultural practice. The potential for agricultural improvement is limited by the extremely acidic soils, dry-season salinity, lack of irrigation water, exposure to tropical cyclones and storm surges, and poor communications within the unit (Brammer 1996).

7.13 Arsenic-Contaminated Soils

Contamination of groundwater by arsenic in the deltaic region, particularly in the Gangetic alluvium of Bangladesh has become one of the world's most important natural calamities. Irrigating with arsenic-contaminated groundwater is adding to the problem of arsenization of many soils of the GBM delta in Bangladesh (Imamul Huq 2008). In Bangladesh, with more than 2,000 soil sample analysed, the average As content has been found well below 10 mg/kg. But in areas where groundwater contamination is reported and where irrigation is practiced, the values have been found to be much higher, ranging up to 58 mg/kg. Moreover, the top 0–15-cm soils contain more As than the 15–30-cm soils. Soils from uncontaminated areas contain <1 mg/kg As on average. Furthermore, the affected soils of the Tista alluvium showed relatively less As in them compared to the affected soils of Gangetic–Meghna alluvium. From the information on soil As thus far gathered, it is becoming apparent that there is a slow build-up of arsenic in many arsenic-affected areas, more particularly in areas where As-contaminated groundwater is used for irrigation (Imamul Huq 2008).

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8 Soil Classification

Due to wide differences in environmental conditions, a large variety of soils have developed in Bangladesh. These soils range from freshly deposited alluvium to very deeply weathered Pleistocene and tertiary sediments. Attempts at the classification of Bangladesh soils have been made since the middle of the nineteenth century. The main purposes of these attempts were to understand the properties of soils in order to determine and increase agricultural productivity. Islam and Islam (1956) first attempted without much field investigation to describe the landscape and soils in Bangladesh by dividing the country into seven broad units that were called *soil tracts*. The basis of this classification was physiographic condition and the geological origin of the parent materials. This classification is used mostly for identifying general soil types even by nonsoil scientists. Table 8.1 shows the seven soil tracts.

The Pleistocene terraces have been divided into two tracts (Madhupur and Barind Tracts) even though their materials are the same and they lie mostly above the flood level. The floodplains have been divided into four tracts based on the rivers from which the materials were derived. The sediments of the Ganges River are calcareous, whereas those of the other three rivers are noncalcareous. The coastal saline tract is tidally affected and the soils are saline.

The land and soil resources of Bangladesh have been subjected to systematic field study with the establishment of the Soil Survey Project of Pakistan (presently Soil Resource Development Institute) in the early 1960s with the active help of the FAO. A long-term program, the Reconnaissance Soil Survey (RSS) was undertaken for identifying and recording properties of all soil taxonomic units at the base level. Intensive interpretation of aerial photographs of landscapes followed by field examination of the soil made along planned traverses across the landscapes was the basis of the RSS. Soil series was chosen as the soil taxonomic unit in this survey. Almost the whole of Bangladesh was covered by the RSS except the Khulna Sundarbans during the period 1965–1976. These surveys covered more than 90 % of the areas of the country. The findings of the surveys were published in 33 reports wherein the physical and chemical properties of identified 476 soil series in the country were described. The total covered area in the RSS was 11,466,913 ha. Forest (which occupies 15 % of the land in Bangladesh) has not been covered by this survey.

All these soil series were morphologically described in the field using the *USDA Soil Survey Manual* (1980). The soil series has been defined as a collection of soil individuals essentially uniform in differentiating characteristics and in arrangement of horizons; or, if genetic horizons are thin or absent, a collection of soil individuals that, within defined depth limits, are uniform in all soil properties diagnostic for the series. Soil series were identified and differentiated from each other based on their characteristics such as texture, nature of the horizon developed, soil reaction, consistence, and the like.

Soils were mapped at the scale of 1:1, 25,000 in terms of geographical associations or complexes of soil series and phases. The mapping unit used in the RSS reports was "SOIL ASSOCIATION" (groups of soils that occur together within part or all of a physiographic unit or subunit). A total of 1,034 soil associations were mapped in Bangladesh. In the soil taxonomic system soil series and soil family are the two lower categories (Soil Staff Survey 1975, 1990).

The areas of individual soil series in Bangladesh range vary widely. The smallest soil series has an area of only 11 hectares whereas the largest one has an area of 486,493 hectares. The average area of a soil series is 23,989 ha.

The number of soil series falling below an area of 1,000 ha is 82. The Kaptai soil series in Bangladesh which has developed on the tertiary rocks covers the largest area (486,493 ha). The Bajuka soil series which has formed on the Surma–Kushiyara floodplain covers the smallest area (only 11 ha) (Hussain et al. 2003). The smaller soil series could be merged with their bigger neighbors where possible on verification of their properties. Where merger is not possible these could be retained as separate soil series. All these soil units

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Table 8.1 The seven soil tracts of Bangladesh

No.	Soil tracts	Area sq km (estimated)	Typical soil series
1	Madhupur tract	10,000	Tejgaon
2	Barind tract	13,000	Amnura
3	Tista Silt	16,000	Gangachara
4	Brahmaputra alluvium	40,000	Ghatail
5	Gangetic alluvium	27,000	Sara
6	Coastal saline tract	20,000	Barisal
7	Chittagong hill tract	15,000	Kaptai

were classified according to two international soil classification systems, the US soil taxonomy (Soil Survey Staff 1975) and the FAO-UNESCO legend (FAO-UNESCO 1990).

Table 8.2 shows the descriptions of the major soil series of the seven tracts.

8.1 Soil Tracts of Bangladesh

The greater part of Bangladesh lies within the delta of the combined Ganges–Brahmaputra–Meghna River system, and is endowed with fertile soils capable of sustained high yields. Soils of each tract have some common characteristic properties different from those of other tracts. Characteristics of each tract are given below and in Fig. 8.1.

8.1.1 Red Soil Tract or Madhupur Tract

It comprises parts of greater Dhaka and Mymensingh districts and extends through isolated tracts in Comilla and Noakhali towards the south in Chittagong. This tract represents red lateritic soils of the Madhupur jungle area, a highland tract above the flood level intersected by numerous gentle depressions locally known as beels, which are highly valued for aman paddies. The soils of this tract have a clayey texture. The soils are deficient in nitrogen, organic matter, phosphate, and lime, but are, however, relatively rich in iron and aluminum and are highly aggregated. They have low base exchange capacity and high phosphate fixing capacity. Addition of organic matter is always helpful. For rice cultivation these soils give a good response to the application of nitrogenous and phosphatic fertilizers. The pH value lies between 5.5 and 6.

8.1.2 Barind Tract

This comprises parts of Greater Rajshahi, Dinajpur, and Bogra districts and covers a total area of 13,000 sq km. The Barind Tract belongs to an old alluvial formation, which is usually composed of massive argillaceous beds of pale reddish brown and often turns yellowish on weathering. Pisoolitic ferruginous concretions (locally known as *kankar*) occur throughout the mass. Transplanted winter paddy is grown in the numerous depressions; the soil is deficient in lime, nitrogen, and phosphorous like the red soils of the Madhupur Tract. The pH varies from 6 to 6.5.

8.1.3 Gangetic Alluvium

It comprises parts of greater Jessore and Kushtia districts and parts of the Rajshahi, Pabna, Khulna, Barisal, Faridpur, and Dhaka districts. It covers an area of 27,000 sq km. This tract represents the riverine lands of the Gangetic plains. The soils are rich and are characterized by high lime content and are well supplied with potash and phosphate, although a small area in the district of Kushtia is rather poor in phosphate. The texture varies from clay loam to light sandy loam according to its formation from the silt of the various tributaries of the Ganges. The soil is generally fertile but responds to the applications of nitrogenous and occasional phosphatic fertilizer. The pH varies from 7 to 8.4.

8.1.4 Tista Silt

This tract comprises parts of Greater Dinajpur, Rangpur, Bogra, and Pabna districts. It covers an area of 16,000 sq km. This represents a sandy loam similar to the ordinary silt soil of Bangladesh. The soil is fertile and is well supplied with potash and phosphate although rather poor in lime. Paddy, tobacco, and sugar cane are the main crops. The soils respond to the application of nitrogen and phosphatic fertilizers. The pH ranges from 6 to 6.5.

8.1.5 Brahmaputra Alluvium

This tract comprises the districts of Greater Comilla, Noakhali, and parts of Mymensingh, Dhaka, Chittagong, and Sylhet districts. The soil is sandy loam, very fertile and rich and is replenished every year by fresh deposits of silt carried down by the floodwater. Almost all kinds of crops are grown of which jute and rice are the most important. The pH varies from 5.5 to 6.8. For lowlying areas, where broadcast winter paddy is grown, application of manure is unnecessary, but on high and medium lands a good response is obtained from the application of nitrogenous and phosphatic fertilizers.

Table 8.2 Tejgaon series, level (forested) phase

Horizon	Depth (in.)	Description
A11	0–1.5	Brown (7.5YR 5/4, dry) to dark brown (7.5YR 3/2, moist) loam; weak fine platy; dry soft; moist very friable and wet nonsticky, nonplastic; many very fine tubular pores; pH 6.1; abrupt smooth boundary
A12	1.5–3	Brown (7.5YR 5/4, dry) to dark brown (7.5YR 4/2, moist) clay loam; weak fine to medium subangular blocky; dry slightly hard; moist friable and wet slightly sticky and slightly plastic; many very fine tubular pores; pH 5.2; abrupt wavy boundary
B1	3–6	Reddish yellow (5YR 6/6, dry) to yellowish red (5YR 4/6 moist) clay; weak medium to coarse subangular blocky; dry hard; moist friable and wet sticky and plastic; many very fine tubular pores; pH 5.2; abrupt wavy boundary
B21–B22	6–19	Light red (2.5YR 6/6, dry) to red (2.5YR 4/6 moist) clay; moderate fine subangular blocky; dry hard; moist firm and wet sticky and plastic; many very fine tubular pores; pH 5.2–5.5; gradual smooth boundary
B23–B25	19–46	As B21–B22; pH 5.6–5.7; gradual smooth boundary
C1–C2	46–62	Light red (2.5YR 6/6, dry) to red (2.5YR 4/6 moist) clay; common fine distinct very pale brown (10YR 7/4, dry) and few fine to medium prominent black (10YR 2/1, dry) mottled; strong fine angular and subangular blocky; dry hard; moist firm and wet very sticky and very plastic; common very fine tubular pores; pH 5.5; gradual smooth boundary
C3–C4	62–76+	Reddish brown (2.5YR 5/4, dry; 4/4 moist) clay; many coarse distinct pale yellow (2.5Y 7/4, dry) and black (10YR 2/1, dry) mottled; strong fine to medium angular and subangular blocky; dry hard; moist firm and wet very sticky and very plastic; common very fine tubular pores; few fine manganese concretions; pH 5.5–5.1
Amnura Series; Level, Intermittently Flooded Phase		
Horizon	Depth (in.)	Description
Ap1 g	0–4	Grey (5Y 5/1) moist to light grey(5Y 7/1) dry with many fine prominent strong brown mottles; silt loam; massive breaking into coarse angular clods; slightly hard dry, very friable moist; nonsticky, slight plastic wet; many fine tubular pores; abrupt smooth boundary; pH 5.5
Ap2 g	4–6	Grey (5Y 5/1) moist to light grey(5Y 7/1) dry with many fine and medium prominent strong brown mottles; silt loam; massive; hard dry, firm moist; nonsticky, slightly plastic wet; common fine tubular pores; abrupt smooth boundary; pH (6.5)
1	6–17	Yellowish brown (10YR 5/6) and light olive-grey(5Y 6/2) moist with fine faint strong brown mottles; silt loam; weak coarse and medium subangular blocky; friable moist, slightly plastic wet; many fine tubular pores; very few, small, hard, spherical iron-manganese nodules; occasional patches of loose, white silty material in vertical cracks and voids; clear smooth boundary; pH 6.9
2	17–26	Grey (5Y 5/1) and Yellowish brown (10YR 5/6) moist with common fine and medium distinct strong brown mottles; silty clay; moderate coarse angular blocky; patchy thin grey cutans along vertical ped faces; firm moist, sticky, plastic wet; common fine tubular pores; very few, small, hard, spherical iron-manganese nodules; occasional patches of loose, white silty material in vertical cracks and voids; abrupt smooth boundary; pH 6.6
3	26–40	Grey (5Y 5/1) moist with common medium and coarse prominent yellowish red and strong brown mottles; silty clay; moderate coarse angular blocky; firm moist, sticky, plastic wet; pores not recorded; very few, small, hard, spherical iron–manganese nodules; clear smooth boundary; pH 6.5
4	40–55	Grey (5Y 5/1) moist with many coarse prominent yellowish red and strong brown mottles; silty clay; firm moist, sticky, plastic wet; pores not recorded; very few, small, hard, spherical iron-manganese nodules; pH 6.4
Gangachara series, Medium Highland Phase		
Horizon	Depth (in.)	Description
Ap1 g	0–5	Olive-grey(5Y 5/2) moist to light grey (5Y 7/1) dry with common fine distinct yellowish brown mottles; loam; massive; nonsticky; nonplastic; friable moist; hard dry; many very fine and fine tubular pores; many very fine and fine roots; abrupt smooth boundary; pH 5.3
Ap2 g	3–5	Grey (5Y 5/1) moist with common fine distinct yellowish brown mottles; loam; massive; slightly sticky; slightly plastic; friable moist; hard dry; common very fine tubular pores; common fine and medium roots; abrupt smooth boundary; pH 5.3
B21	5–12	Olive-grey (5Y 5/2) moist with few fine distinct yellowish brown mottles; silt loam; weak very coarse prismatic; slightly sticky, nonplastic; very friable moist; continuous moderately thick gray cutans on vertical ped faces; many very fine and fine tubular pores; few fine roots; abrupt smooth boundary; pH 6.6
B22	12–23	Olive-grey (5Y 5/2) moist with many fine distinct yellowish brown mottles; silt loam; weak very coarse prismatic; nonsticky, nonplastic; very friable moist; continuous moderately thick olive-grey cutans on vertical ped faces; many very fine and fine tubular pores; few fine roots; abrupt smooth boundary; pH 7.1

(continued)

Table 8.2 (continued)

Horizon	Depth (in.)	Description
B23	23–28	Olive (5Y 5/3) moist with many fine distinct dark yellowish brown and common fine distinct yellowish brown mottles; silt loam; weak very coarse prismatic; nonsticky, nonplastic; friable moist; continuous moderately thick olive-grey cutans on vertical ped faces; many very fine and fine tubular pores; abrupt smooth boundary; pH 7.1
B24	20–34	Olive (5Y 5/3) moist with many medium and coarse distinct yellowish brown mottles; silt loam; moderate very coarse prismatic; slighty sticky, slightly plastic; farm moist; continuous thick olive-grey cutans on vertical ped faces; many very fine and fine tubular pores; abrupt wavy boundary; pH 7.1
IIA1b	34–37	Dark grayish brown (2.5Y 4/2) moist with many fine distinct dark yellowish brown mottles; silt loam; weak very coarse prismatic; sticky, nonplastic; firm moist; continuous moderately thick olive-grey cutans on vertical ped faces; abrupt smooth boundary; pH 6.7 (7.5)
IIC	37–51	Grayish brown (2.5Y 5/2) and yellowish brown (10YR 5/5) moist, sandy loam; nonsticky, nonplastic; loose moist; pH 7.0 (7.5)
Ghatail series		
Horizon	Depth (in.)	Description
Ap1	0–2	Silty clay; very dark grey (2.5Y 3/1 moist) with common fine distinct dark brown (7.5YR 4/4) mottles; moderate coarse and medium cloddy and medium and fine granular structure with common fine tubular pores; plastic and nonsticky when moist; many fine roots; strongly acid abrupt smooth boundary; pH 5.5
Ap2	2–4	Clay; very dark grey (2.5Y 3/1 moist) with common fine distinct dark brown (7.5YR 4/4) mottles; massive with few fine tubular pores; plastic and nonsticky when moist; many fine roots; strongly acidic abrupt wavy boundary; pH 5.5
A3	4–8	Clay; dark grey (5Y 4/1 moist) with common fine distinct dark yellowish brown (10YR 4/4) mottles; moderate coarse angular blocky structure, with common fine tubular pores and medium nearly continuous dark grey coatings along vertical and horizontal ped faces and pores; plastic and nonsticky when moist; common fine roots; neutral clear smooth boundary; pH 7.0
B2	8–26	Clay; dark grey (5Y 4/1 moist) with common fine distinct dark yellowish brown (10YR 4/4) mottles; moderate coarse angular blocky structure, with common fine tubular pores and medium nearly continuous dark grey coatings along vertical and horizontal ped faces and pores; plastic and nonsticky when moist; common fine roots; neutral clear smooth boundary; pH 7.0
B3	26–35	Silty clay; dark grayish brown (2.5Y 4/2 moist) with many medium distinct yellowish brown (10YR 5/8) mottles; moderate very coarse prismatic weak coarse angular blocky structure, with common fine tubular pores and medium nearly continuous dark grey coatings along vertical and horizontal ped faces and pores; slightly firm when moist; mildly alkaline gradual boundary; pH 7.5
C1	35–45	Clay; dark grey (10YR 4/1 wet) finely mottled dark yellowish brown mottles; moderate very coarse prismatic structure, with few fine tubular pores and medium continuous coatings along vertical ped faces and pores; plastic and slightly sticky when wet; mildly alkaline clear smooth boundary; pH 7.5
C2	45–50	Clay loams; grey (5Y 5/1wet) with many fine distinct yellowish brown (10YR 5/6) mottles; massive with few fine tubular pores and thin continuous coatings along pores; consistence not observed; mildly alkaline; pH 7.5
Sara series, Medium Highland, Smooth relief phase		
Horizon	Depth (in.)	Description
Apg	0–5	Light grey (5Y 7/2, dry) and grey (5Y 5/1, moist) silty clay loam; few fine distinct yellowish brown (10YR 5/6, dry) mottles; massive; dry slightly hard, moist friable; common fine tubular pores; slightly calcareous; abrupt smooth boundary; pH 7.0 (8.0)
A1 g	5–11	Pale olive (5Y 6/3, dry) to olive-grey (5Y 5/2, moist) silt loam/silty clay loam; common fine distinct light yellowish brown (2.5Y 6/4, dry) mottles; weak coarse prismatic and fine and medium angular blocky; patchy thin grey coatings around peds and in pores; dry slightly hard, moist friable; many fine tubular pores; many broken shells; strongly calcareous; clear wavy boundary; pH 7.8
C1-3	11–30	Pale olive (5Y 6/3, dry) to olive-grey (5Y 5/2, moist) silt loam; common fine distinct light yellowish brown (10YR 6/4, dry) mottles; (structure not recorded) dry soft, common fine tubular pores; strongly calcareous; clear wavy boundary; pH 7.8
Barisal series, Medium Highland, Nonsaline phase		
Horizon	Depth (in.)	Description
Ap1	0–5	Pale olive (5Y 6/3) moist with few fine faint olive mottles; silty clay; massive; slightly sticky, slightly plastic wet, firm moist; common medium tubular and vesicular pores; common very fine roots; noncalcareous; abrupt, smooth boundary; pH 7.5 (6.5)

(continued)

Table 8.2 (continued)

Horizon	Depth (in.)	Description
Ap2	5–7	Olive brown grey (5Y 5/2) moist with common coarse distinct dark greenish grey and dark yellowish brown mottles; silty clay; massive; sticky, plastic wet, very firm moist; partially glayed; few very fine roots; noncalcareous; abrupt, smooth boundary; pH 7.5 (8.0)
B21	7–12	Grey (5Y 5/1) moist with many medium prominent yellowish red mottles; silty clay; strong coarse prismatic breaking into strong coarse to subangular blocky; sticky, slightly plastic wet, firm moist; patchy thin grey cutans along horizontal and vertical ped faces; common medium tubular pores; common very fine roots; abrupt, smooth boundary; pH 5.5
B22	12–21	Dark grey (5Y 4/1) moist with common few prominent yellowish red few fine distinct yellowish brown mottles; clay; moderate coarse prismatic; sticky, plastic wet, firm moist; continuous moderate thick grey cutans along vertical ped faces; common fine and medium tubular pores; noncalcareous; clear, smooth boundary; pH 4.6 (8.0)
C1	21–30	Dark grey (5Y 4/1) moist with common fine prominent yellowish yellowish red mottles; silty clay; weak very coarse prismatic; sticky, plastic wet, firm moist; continuous moderate thick grey cutans along vertical ped faces; common fine and medium tubular pores; noncalcareous; clear, smooth boundary; pH 4.2
C2	30–37	Dark grey (5Y 4/1) moist; silty clay; weak very coarse prismatic; sticky, plastic wet, firm moist; patchy moderately thick grey cutan along vertical ped faces; common medium tubular pores; few fine roots; noncalcareous; abrupt, smooth boundary; pH 4.4
IIA1b	37–51	Dark grey (5Y 4/1) moist; silty clay loam; weak very coarse prismatic; sticky, plastic wet, firm moist; patchy moderately thick grey cutan along vertical ped faces; common medium tubular pores; few fine roots; noncalcareous; abrupt, smooth boundary; pH 4.5
IIIC3	51–66	Dark grey (5Y 4/1) moist; silty clay; sticky, plastic wet, noncalcareous; pH 4.1
Kaptai series		
Horizon	Depth (in.)	Description
A1	0–3	Dark brown (10YR 4/3) moist; fine sandy loam; weak granular; pH 5.5; (worm casts surface have pH 6.3)
B1	3–9	Yellowish brown (10YR 5/6) moist; silt loam; weak sub granular blocky; friable; pH 5.5
B2	9–20	Strong brown (7.5YR 5/6) moist; silty clay loam; massive; friable; pH 5.4
B3	20–36	As B2 but occasional fragments of fine-grained sandstone with manganese
C1	36–60	As B2 and B3, but many sandstone fragments; pH 5.4

8.1.6 Coastal Saline Tract

This tract comprises Greater Barisal, Khulna, parts of Noakhali, and Chittagong, the flat lowlying areas of the coastal belt and estuarine *charland* and covers an area of 20,000 sq km. From the south, near the sea are the Sundarbans, a region of morasses and swampy islands most of which is covered with dense evergreen forest, with some covered with salt water at flood tide. The soil is saline and salt efflorescence occurs in many places. The soil is well supplied with potash and phosphate. The soils are neutral to slightly alkaline in reaction.

8.1.7 Chittagong Hill Tracts

This tract comprises the Chittagong and Garo hills in the Greater Mymensingh district. It covers a total area of about 15,000 sq km. The soils consist of hard red clay with a mixture of fine brown sand. The soils are slightly to strongly acidic, and sometimes shallow over shale or sandstone bedrocks on very steep high hills. Mostly these types of soil are used for *Jhum* (shifting cultivation) cultivation. Correlation of the seven soil tracts with subsequently expanded physiographic units and general soil types are shown in Table 8.3.

8.2 Classification of Bangladesh Soils Based on USDA Soil Taxonomy

The soil taxonomy is a dichotomous system that has been used for the classification of Bangladesh soils. This system contains two sets of categories: the higher categories include order, suborder, great group, and subgroup, and the lower categories include series and association. Five orders occur in Bangladesh. These are: Entisols, Inceptisols, Alisols, Ultisols, and Histosols (Table 8.4). Twelve suborders, around 21 great groups, and 56 subgroups have been identified in Bangladesh. A list of higher categories identified in the country is given in Table 8.4. A brief description of the soil orders found in Bangladesh follows.

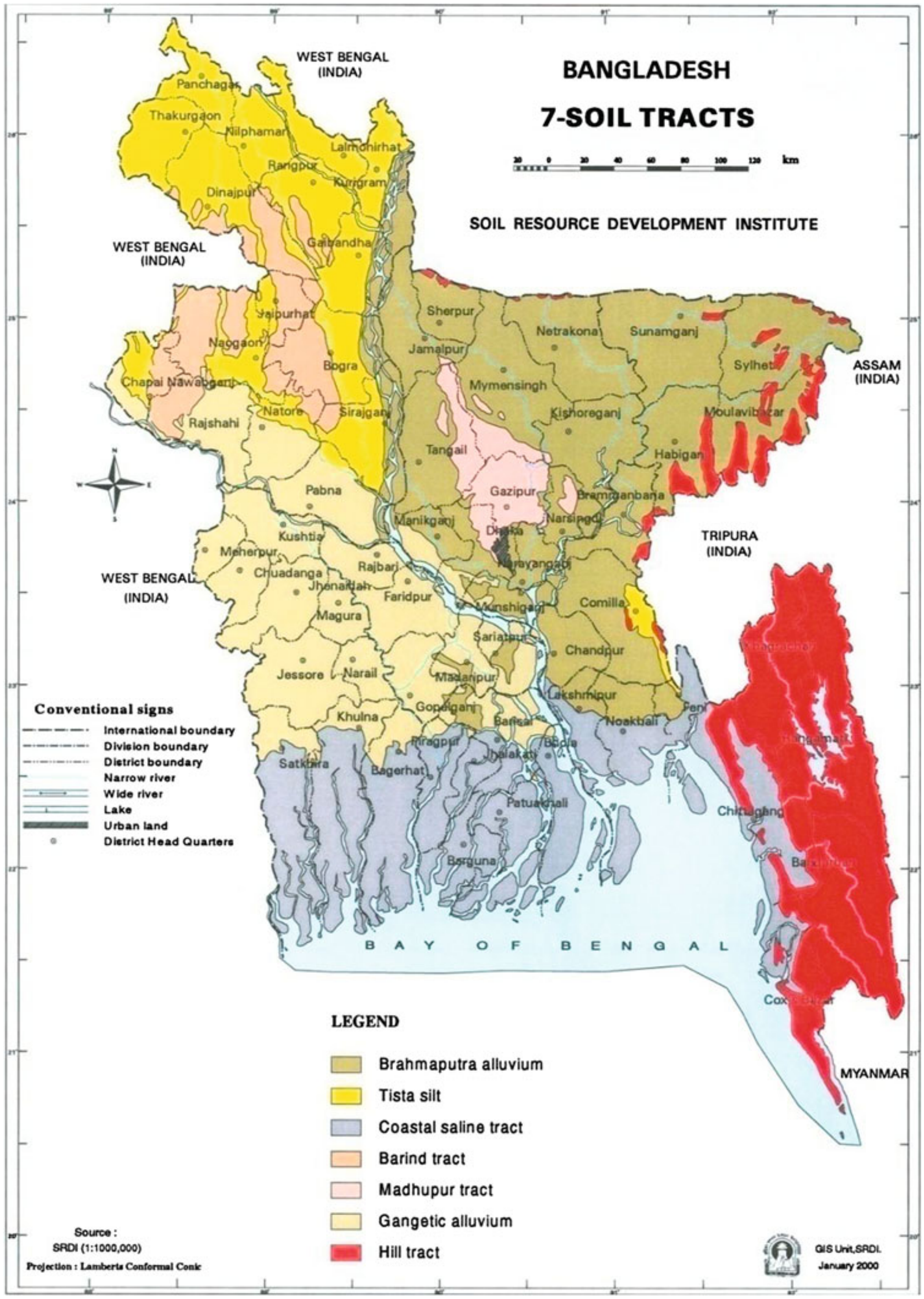

Fig. 8.1 The soil tracts of Bangladesh (*Source* SRDI)

8.2.1 Entisols

Entisols occur mainly in the floodplains that lack a cambic horizon. Part of the estuarine floodplain, meander floodplain, non-Gangetic and Gangetic floodplains belong to this order. Floodplain soils that dry up regularly during the dry season and are subject to intermittent floods are included in Entisols. The soils are poorly and imperfectly drained with either a prismatic or blocky subsoil structure. The organic carbon content decreases with depth and reaches a level of 0.2 % or less within a depth of 1.25 m from the surface. Although they do not fulfill the criteria of cambic horizon, some soils of the floodplains possess iron manganese concretions in the structured layers. These soils are classified as haplaquents. The tidally flooded and estuarine floodplain soils that lack subsoil structure but may have the bulk density of more than 1.0 gm/cc are classified as fluvaquent.

Table 8.3 The correlation of seven soil tracts with subsequently expanded physiographic units or subunits and general soil types

Soil tract	Physiography units	General soil types
1. Madhupur tract	Madhupur tract	Red-brown terrace soil
2. Barind tract	Barind tract	Grey terrace soil
		Deep red-brown terrace soil
3. Gangetic Alluvium	Ganges River floodplain Arial beel Gopalganj–Khulna peat basins Ganges tidal floodplain (nonsaline part)	Calcareous dark grey floodplain soil Acid basin clay peat grey floodplain soil
4. Tista silt tract	Old Himalayan piedmont plain Tista floodplain	Black Terai soil
		Noncalcareous brown floodplain and grey floodplain soil
		Grey floodplain and noncalcareous brown floodplain soil
		Noncalcareous dark grey floodplain soil
		Noncalcareous alluvium
		Noncalcareous grey floodplain soil (nonsaline phase)
		Noncalcareous alluvium
5. Brahmaputra alluvium	Jamuna floodplain	Noncalcareous brown floodplain and grey floodplain soil
	Old Brahmaputra floodplain	
	Haor Basin	Grey floodplain and noncalcareous brown floodplain soil
	Surma–Kushiyara floodplain	
	Middle Meghna floodplain	Noncalcareous dark grey floodplain soil
	Old Meghna estuarine floodplain	Grey floodplain soil
	Young Meghna estuarine floodplain (northern part) Chittagong coastal plain Northern and eastern piedmont plain	Acid basin clay
		Surma–Kushiyara floodplain soil Comilla basin soil
		Grey floodplain and noncalcareous dark grey floodplain soil
		Calcareous alluvium (nonsaline part) Noncalcareous alluvium
		Floodplain soil
		Old piedmont plain soil
6. Coastal saline tract	Young Meghna estuarine floodplain	Calcareous alluvium (saline phase) Acid sulphate soil
	Ganges tidal floodplain (saline part)	Grey floodplain soil (saline phase)
	Sundarban Chittagong coastal plain (partly)	Grey piedmont soils (saline part)
7. Hill Tract	Northern and eastern hills	Brown hill soil

8.2.2 Inceptisols

Inceptisols occur in all three physiographic units: floodplains, terraces, and hills. The soils under Inceptisols occupy more than 70 % of the country. They have moderately developed soils with one or more horizons. The poldered estuarine floodplain, meander floodplain, non-Gangetic floodplain, quaternary terrace, and tertiary hill soils having cambic B horizon are included in this order. These soils have hydromorphic properties and organic matter content regularly declines with depth and reaches a level of 0.2 % or less to a depth of 1.25 cm. Inceptisols show evidence of pedogenic alteration of iron manganese concretions of fine sand or coarser sizes. The mottles of low chroma develop in hydromorphic soils although in some cases the mottles may develop very rapidly before the removal of flood water. The mottle may form into concretions with the pases of lime. The soil mass consists of concretions at least 0.25 % by weight to be considered adequate for a cambic horizon. They have a significant amount of weatherable minerals.

8.2.3 Alfisols

Alfisols are well drained with an argillic horizon. The quaternary terrace soils belong to this order. These soils belong to the ustic soil moisture regime. The base saturation of these soils in all parts of the argillic horizon is high (>35 %). The fluctuation of the groundwater table in terraces contributes to a relatively higher base saturation in these horizons. Organic matter content in most of the profile

Table 8.4 List of upper categories of USDA soil taxonomy identified in Bangladesh

Order	Suborder	Great group	Sub group
Entisols	Aquents	Fluvaquents	Typic Fluvaquents
			Aeric Fluvaquents
			Tapta–Histic Fluvaquents
		Haplaquents	Typic Haplaquents
			Aeric Haplaquents
			Mollic Haplaquents
		Hydraquents	Haplic Haplaquents
		Psammaquents	Typic Psammaquents
			Aeric Psammaquents
	Arents	Arents	Arents
	Fluvents	Udifluvents	Aquic Udifluvents
	Psamments	Ustipsamments	Typic Ustipsamments
			Aquic Ustipsamments
Inceptisols	Aquepts	Albaquepts	Typic Albaquepts
			Aeric Albaquepts
			Ultic Albaquepts
		Haplaquepts	Typic Haplaquepts
			Aeric Haplaquepts
			Humic Haplaquepts
			Mollic Haplaquepts
			Sulphic Haplaquepts
			Thapto–Histic Haplaquepts
		Humaquepts	Typic Humaquepts
			Cumulic Humaquepts
			Fluvaquentic Humaquepts
			Thapto–Histic Humaquepts
		Sulphaquepts	Typic Sulphaquepts
	Ochrepts	Dystrochrepts	Typic Dystrochrepts
			Aquic Dystrochrepts
			Fluvaquentic Dystrochrepts
			Ultic Dystrochrepts
		Eutrochrepts	Typic Eutrochrepts
			Aquic Eutrochrepts
			Aquic Dystric Eutrochrepts
			Dystric Eutrochrepts
		Ustochrepts	Typic Ustochrepts
			Aquic Ustochrepts
			Lithic Ustochrepts
			Udic Ustochrepts
			Ultic Ustochrepts
	Umbrepts	Haplumbrepts	Typic Haplumbrepts
			Eutric Haplumbrepts
			Pachic Haplumbrepts
			Petroferric Haplumbrepts

(continued)

Table 8.4 (continued)

Order	Suborder	Great group	Sub group
Mollisols	Aquolls	Haplaquolls	Typic Haplaquolls
			Fluvaquentic Haplaquolls
Ultisols	Ustults	Haplustults	Plinthic Haplustults
		Paleustults	Typic Haplustults
			Plinthic Haplustults
			Rhodic Haplustults
Histosols	Fabrists	Medifibrists	Typic Medifibrists
			Fluvaquentic Medifibrists
	Hemists	Medihemists	Typic Medihemists
			Fluvaquentic Medihemists
	Saprists	Medisaprists	Typic Medisaprists

Source Hussain 1992

decreases regularly with depth but remains consistently higher than 0.2 % below a depth of 1.25 m from the surface. In older sediments, the organic matter content decreases regularly with depth and reaches a very low level in the deeper horizons.

8.2.4 Ultisols

The well-drained hill soils with an argillic horizon and a base saturation of <35 % belong to the order Ultisols. They have an udic soil moisture regime. These soils are classified as tropudults, and contain more than 10 % weatherable minerals in 20–200 μm in the upper 50 cm of the argillic horizon.

8.2.5 Histosols

Histosols consist of the soils that have an histic horizon more than 40 cm thick, either at the surface or in one or more layers. In Bangladesh, Histosols occur extensively in the Gopalganj–Khulna beels. They contain organic layers of varying degrees of decomposition. Histosols include seven soil series of which six are classified as undifferentiated Histosols.

8.3 FAO-UNESCO Soil Map of the World/ Legends

The FAO-UNESCO Soil Map of the World is an international system for classifying soils. In this system, classification is based on the recognition of a number of closely defined diagnostic horizons. In the FAO-UNESCO legend, soils have been classified up to subunit levels. The FAO-UNESCO legend is similar to the USDA Soil Taxonomy in the classification and mapping of Bangladesh soils. In the FAO-UNESCO Soil Map of the World, the highest classification category is the major soil groupings, which is approximately equivalent to the suborder level of the USDA Soil Taxonomy. A total number of four major soil groups have been identified. The major soil groups that are found in Bangladesh are briefly discussed below (FAO-UNDP 1988).

8.3.1 Fluvisols

These are young soils developed in recent alluvium that is raw or stratified within a few centimeters from the surface. The main problem of these soils is the rapid changes either by erosion or deposition. Where the soils are not quickly eroded or repeatedly buried by new materials, they develop a cambic B horizon that extends below 25 cm within a few years and are classified as gleysols. Fluvisols comprise most of the noncalcareous and calcareous alluvium soils of the general soil types. They are characteristic of active flood plains where new alluvium is regularly deposited, but they also occur on some older floodplains where perennially wet conditions prevent deep soil development. In the USDA Soil Taxonomy, these soils are included in the Entisols.

8.3.2 Gleysols

Gleysols are most extensive in Bangladesh. They are developed in floodplain, piedmont, and terraces where a

Table 8.5 Correlation of general soil types of Bangladesh with the FAO-UNESCO legend and the US Soil Taxonomy

General soil types	FAO-UNESCO soil subunits	USDA Soil Taxonomy
Floodplain soils		
1. Calcareous alluvium	Areni–Calcaric Fluvisols	Typic Fluvaquents
	Chromi–Calcaric Fluvisols	Aeric Fluvaquents
	Orthi–Calcaric Fluvisols	Typic Psammaquents
	Calcaric–Cambic Arenosols	Aquic Udifluvents
2. Noncalcareous alluvium	Areni–Eutric Fluvisols	Typic Fluvaquents
	Chromic–Eutric Fluvisols	Aeric Fluvaquents
	Orthi–Eutric Fluvisols	Thapto-Histic Fluvaquents
	Chromic–Dystric Fluvisols	Typic Psammaquents
	Histic–Eutric Fluvisols	Aeric Haplaquents
	Histic–Umbric Fluvisols	Aquic Ustipsamments
	Gleyi–Cambic Arenosols	Aeric Psammaquents
3. Calcareous brown floodplain soils	Chromi–Calcaric Gleysols	Typic Eutrochrepts
	Calcaric–Gleyic Cambisols	Aquic Eutrochrepts
4. Calcareous grey floodplain soils	Chromi–Calcaric Gleysols	Typic Haplaquepts
		Aeric Haplaquepts
5. Calcareous dark grey floodplain soils	Chromi–Calcaric Gleysols	Typic Haplaquepts
	Verti–Calcaric Gleysols	Aeric Haplaquepts
	Fluvi–Calcaric Gleysols	Typic Eutrochrepts
6. Noncalcareous grey floodplain soils	Areni–Eutric Gleysols	Typic Haplaquepts
	Chromi–Eutric Gleysols	Aeric Haplaquepts
	Chromi–Dystric Gleysols	Thapto-Histic Haplaquepts
7. Calcareous brown floodplain soils	Chromi–Dystric Gleysols	Udic Ustochrepts
	Chromi–Eutric Gleysols	Aquic Dystric Eutrochrepts
	Orthi–Dystric Cambisols	Aquic Dystochrepts
	Orthi–Haplic Alisols	Ochreptic Haplustults
8. Noncalcareous dark grey floodplain soils	Chromi–Eutric Gleysols	Typic Haplaquepts
	Molli–Eutric Gleysols	Aeric Haplaquepts
	Umbri–Eutric Gleysols	Thapto-Histic Haplaquepts
	Verti–Eutric Gleysols	Mollic Fluvaquents
9. Black terai soils	Chromi–Mollic Gleysols	Typic Haplumbrepts
	Chromi–Umbric Gleysols	Pachic Haplumbrepts
	Orthi–Umbric Gleysols	Cumulic Humaquepts
10. Acid basin clays	Chromi–Dystric Gleysols	Typic Haplaquents
	Chromi–Eutric Gleysols	Typic Haplaquepts
	Verti–Eutric Gleysols	Aeric Haplaquepts
11. Acid sulfate soils	Chromi–Thionic Fluvisols	Typic Sulfaquepts
	Chromi–Thionic Gleysols	Sulfic Haplaquepts
12. Peat	Dystric Histosols	Histosols
	Eutric Histosols	Typic Medisaprists
13. Grey piedmont soils	Chromi–Dystric Gleysols	Typic Haplaquepts
	Chromi–Eutric Gleysols	Aeric Haplaquepts
14. Brown piedmont soils	Orthi–Dystric Cambisols	Aquic Dystrochrepts
	Orthi–Gleyic Cambisols	Ultic Ustochrepts

(continued)

Table 8.5 (continued)

General soil types	FAO-UNESCO soil subunits	USDA Soil Taxonomy
Hill soils		
15. Brown hill soils	Lepti–Dystric Cambisols	Lithic Ustorthents
	Orthi–Dystric Cambisols	Udic Ustochrepts
	Orthi–Dystric Leptosols	Dystric Eutrochrepts
	Orthi–Haplic Luvisols	Typic Dystrochrepts
	Orthi–Ferric Alisols	Typic Haplustults
	Ferri–Gleyic Alisols	Aquic Haplustults
	Orthi–Haplic Alisols	Typic Paleustults
	Eutri–Cambic Arenosols	Ultic Haplustalfs
Terrace soils		
16. Shallow red-brown terrace soils	Chromi–Calcaric Gleysols	Aquic Ustochrepts
	Verti–Eutric Gleysols	Aquic Paleustults
	Orthi–Gleyic Alisols	Aquic Haplustults
17. Deep shallow red-brown terrace soils	Orthi–Ferric Alisols	Typic Paleustults
	Orthi–Ferric Luvisols	Typic Haplustults
18. Brown mottled terrace soils	Orthi–Ferric Luvisols	Typic Paleustults
	Orthi–Ferric Alisols	Typic Paleustalfs
19. Shallow grey terrace soils	Chromi–Eutric Planosols	Typic Albaquepts
	Verti–Eutric Planosols	Aeric Albaquepts
20. Deep grey terrace soils	Chromi–Albic Gleysols	Aeric Albaquepts
	Chromi–Eutric Planosols	Albic Paleaqults
21. Grey valley soils	Chromi–Albic Gleysols	Aeric Albaquepts
	Chromi–Eutric Gleysols	Aeric Haplaquepts
22. Man-made land	Calcari–Fimic Anthrosols	Arents (Undifferentiated)
	Eutri–Fimic Anthrosols	
	Gleyi–Fimic Anthrosols	

cambic B horizon has formed within the upper 50 cm of the profile. The soils have gleyic properties indicating seasonally or perennially wet conditions. Gleysols include almost all noncalcareous and calcareous grey and dark grey floodplain soils, deep grey terrace soils, and grey terrace soils, as well as some acid sulphate soils, grey piedmont soils, and acid basin clays. They are included in the Inceptisols of the USDA Soil Taxonomy. A total of 304 soil series have been included in this major grouping, which has 8 soil units and 21 subunits.

8.3.3 Cambisols

Cambisols have loamy and clay soils with a cambic B horizon that does not show gleyic properties. Cambisols occur extensively in some hill areas and more locally on some high floodplains and piedmont ridges. They include mainly brown hill soils and noncalcareous brown floodplain soils, but also include some calcareous brown floodplain soils and black Terai floodplain soils of the general soil types. In the USDA Soil Taxonomy, they are included with the Inceptisols. Clay skins are present on the faces of peds and pores in argillic horizons. Where such evidence is considered inadequate, the B horizon is considered to be cambic and the soils are classified as cambisols. There are 5 soil units and 14 subunits in this group.

8.3.4 Luvisols

These soils have an argic B horizon. In these soils, clays have been leached from the topsoil into the subsoil. The cation exchange capacity of these soils is 16 meq % or more and percent base saturation is 50 or more. Luvisols occupy relatively small areas in parts of the Barind Tract, Madhupur Tract, and some hill areas. They include brown hill soils, deep red-brown terrace soils, brown mottled

terrace soils, and deep grey terrace soils. In the USDA Soil Taxonomy, these are included with alfisols, mainly haplusalfs. There are 3 soil units and 5 subunits recognized in this grouping (Table 8.5).

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9 Key Soil Series

Although Bangladesh is relatively smaller in extent, it has a surprisingly wide range of soils. About 465 soil series were identified during the reconnaissance soil survey of the country. Information on all the soil series is compiled from the Reconnaissance Soil Survey Reports (RSSR) published by what was then the Soil Survey project of Pakistan and is presently the Soil Resource Development Institute (SRDI), during the period of 1963–1975.

A soil series is a group of soils that have formed in the same way from the same kind of parent material under similar conditions of climate, vegetation, drainage, and time. As they are formed in the same way, the soils within a soil series have the same number and kinds of soil horizons (layers) that have similar characteristics such as texture, structure, consistence, and reaction (acidity/alkalinity). However, it needs to be understood that the soils within a series are not identical. As the term *series* implies, they include a range of soils. The soil series is considered a carrier to disseminate agricultural technology from one known area to another area confidently.

A soil series name is generally derived from a town or landmark in or near the area where the soil series was first recognized; for example, the Mehendiganj soil series was described and identified in and around Mehendiganj only.

Although it is the lowest unit of the USDA Soil Taxonomy, in Bangladesh identified soil series are yet to be correlated for classification. As a result soils with almost similar properties are placed in two or more different soil series. That is why soil series identification at field level is somewhat different and sometimes time consuming, and there is no literature available to be used as a guide.

As has been mentioned earlier, Bangladesh has three broad physiographic units: the floodplain, which is about 80 % of the total land area; the terrace, which comprises about 8 % of the total land area; and the hills, constituting about 12 % of the total land area. Within each of these broad physiographic units there are zonal differences in topography, soils, drainage, and hydrological condition upon which they are divided into 20 physiographic units. Tables 9.1 and 9.2 list the soil series according to broad physiographic units.

Table 9.3 is a list of the soil series of Bangladesh as per the RSS report with their extent, parent materials, and classification in the USDA soil subgroups. The series are arranged alphabetically.

It needs to be mentioned here that in the RSS report, 476 soil series were recognized. However, during the semi-detailed soil survey, some of the soil series have been merged with another series where more than 80 % of the characteristics of the series were found to be similar. One example is the Kalma/Kashimpur/Noadda series. All these series have been merged with the Tejgaon series.

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Table 9.1 List of soil series according to broad physiographic unit of Bangladesh

Physiographic unit	Number of soil series	Soil series
1. Old Himalayan piedmont Plain	23	Alsia, Atiagram, Atwari, Baliadangi, Benghari, Bhajanpur, Birgonj, Charol, Hisabia, Jagdal, Lakhiopur, Nandigram, Nayabati, Nekmarad, Pamol, Panchagarh, Ranishankail, Ruhea, Salandar, Satoya, Silaikuthi, Tarala, Tetulia
2. Tista Meander Floodplain	37	Amgaon, Bajra, Balua, Bhimpur, Bonarpara, Chilmari, Dhunat, Digli, Dimla, Dohali, Domar, Farabari, Gabtali, Gangachara, Hasnabad, Imadpur, Indrail, Jaldhaka, Jamun, Kachna, Kakina, Kaunia, Lashkara, Majpara, Malanchi, Manda, Menanagar, Naldanga, Palasbari, Pirgachha, Sarala, Shaghatta, Srirampur, Tista silty alluvium, Ulipur, Uttargaon
3. Karotoa Bangali Floodplain	07	Goalgram, Horgathi, Matia, Poradi, Sariakandi, Srikola, Ullapara
4. Lower Atrai Basin	17	Beola, Bhutlia, Deopara, Elanga, Halti, Hulibari, Jaonia, Kanil, Lalor, Mallika, Mainam, Payna, Piprul, Safapur, Saluka, Satbaria, Serkol
6. Brahmaputra Floodplain	42	Balina, Barachar, Barhatta, Brahmaputra sandy alluvium, Brahmaputra silty alluvium, Charmara, Daspara, Dhamrai, Diarkandi, Dulalpur, Ghatail, Gorargaon, Gouripur, Hamidpur, Ichamati, Iswargang, Jamalpur, Jamtail, Kajla, Kamarkhanda, Kanchanpur, Kendua, Khaira, Khalerchar, Lokdeo, Maldaha, Melandaha, Mohangang, Munsumi, Nagarbari, Nakla, Nandail, Pagla, Phulpur, Sabharbazaar, Shamgong, Sherpur, Silmandi, Singair, Sonatala, Sribordi, Tarakanda
7. Ganges River Floodplain	56	Amjhupi, Arial, Arunbari,Baliakandi,Bangaon, Basail, Batra, Benapol, Bera, Darsana, Dhalat, Dubalia, Dulai, Ganges sandy alluvium, ganges silty alluvium, Gangni, Garuri, Ghior, Gomastapur, Gopalpur, Gournadi, Hijla, Ishurdi, Jayanti, Kalbadar, Kasiani, Kathuli, Katra, Kiranchi, Koladi, Kumarkhali, Kuslia, Maheshpur, Manikdi, Maria, Mehendiganj, Mirpur, Muladi, Narail, Naria, Noapara, Pakuria, Pangsa, Patharghata, Puspakati, Ramdia, Rathuria, Rayna, Ruppur, Santhia, Sara, Aujanagar, Sukdebpur, Tahirpur, Tarpassa, Teghar
8. Ganges Tidal Floodplain	17	Asasuni, Bajaoa, Barisal, Betagi, Dacope, Daulatpur, Dumuria, Elachur, Hogla, Jhalakati, Kakmari, Kamalkathi, Nalchiti, Pirojpur, Ramgati, Tetla, Tidal silty alluvium
9. Gopalganj–Khulna Peat Basins	03	Harta, Rajoir, Satla
11. Meghna River Floodplain	26	Bajora, Bancharampur, Bashanda, Biruli, Borda, Chandpur, Chandragonj, Cheora, Chhilania, Companyganj, Dagan, Dakatia, Faridganj, Fuldi, Homna, Kalatia, Madhabpur, Madna, Manikandi, Matlab, Paikpara, Rampal (made land), Satnal, Tangerchar, Turag
12. Meghna Estuarine Floodplain	33	Astagram, Bagdha, Baniyachung, Barura, Batazor, Belna, Betbaria, Bhola, Burichang, Chandina, Debidwar, Dhamti, Godnail, Gumti, Hatiya, Humayunpur, Ikram, Ilsa, Jalkundi, Kotwalipara, Madra, Muradnagar, Musapur, Naraibag, Nilkamal, Palang, Paysa, Richi, Sandwip, Sangar, Siddhirganj, Tippera, Wazipur
13. Surma- Kushyara Floodplain	23	Ajmiriganj, Bajuka, Balagonj, Bamati, Dirai, Goyainghat, Hakaluki, Inathganj, Kadipur, Kanaighat, Khasgaon, Kusiyara, Madhaynagar, Nabinagar, Nasirnagar, Phagu, Rauli, Sarail, Srighar, Sulla, Tajpur, Terchibari, Titas
14. Northern and Eastern Piedmont Plains	56	Bahubal, Balisira, Belonia, Bharella, Bhugai, Bhusna, Bijipur, Birinchi, Chakla, Chinakuri, Chandraghona, Dharmapasha, Dolu, Durgapur, Fatehpur, Hoanak, Itakhola, Jaflong, Jaliganj, Jhinaighati, Juri, Kaipara, Kangsa, Karnaphuli, Manu, Marisi, Markuli, Mirsarai, Moghachhari, Nalitabari, Nunni, Olipur, Pahartali, Palashtala, Panchalis, Pritimpasa, Purbabagh, Ramnagar, Rangari, Ratna, Ruma, Sachna, Sahajibazar, Saktola, Sankochail, Sarta, Satgaon, Selapur, Someswari, Srimangal, Subhapur, Susang, Sutang, Swalak, Sylok, Tarapur
15. Chittagong Coastal Plains	25	Badarkhali, Barabakaria, Bhatiari, Chakaria, Cheringa, Dhurang, Feni, Gahira, Gundum, Halda, Harbang, Karnaphuli sandy alluvium, Karnaphuli silty alluvium, Kumira, Kutubdia, Monakhali, Muhari, Nhila, Noapara, Noachari, Patenga, Raojan, Rangunia, Ukhiya, Whaikyang
16. St Martin's Coral Island	05	Coral Beach sand, Dakhinpara, Jinjira, Narikhaldia, Teknaf

(continued)

Table 9.1 (continued)

Physiographic unit	Number of soil series	Soil series
17. Barind Tract	22	Adatala, Amnura, Atahar, Ayda, Binsara, Chakaria, Choumaka, Dudnai, Ekdala, Gayra, Guldaha, Gulta, Jhikra, Jhilima, Kahalu, Lauta, Nachol, Nijhuri, Pauali, Puna, Sahapur, Taras
18. Madhupur Tract	23	Belabo, Chandra, Kalma, Kashimpur, khilgaon, Noadda, (these soil series were also identified in the Barind Tract), Bhatpara, Chhiata, Demra, Genda, Gerua, Gazipur, Jatrabari, Karail, Kirtankhola, Naga, Nayanpur, Payati, Rajasan, Salna, Sayek, Tejgaon, Tejkunipara
19. Northern and Eastern Hills	42	Barkal, Baralekha, Beanibazar, Belaichari, Bulako, Chhatak, Chinaura, Dantmara, Dhum, Gajni, Ghagra, Ghosgaon, Hazaribak, Hiakhu, Jaldi, Jibanpur, Kalapani, Kamuri, Kankrachari, Kaptai, Karerhat, Kassalong, Khadimnagar, Kharera, Khiram, Kotbari, Kulaura, Lakhichara, lalmai, Lama, Nalua, Ramgarh, Rangamati, Rangapani, Rankhiang, Sajek, Salban,Sitakunda, Srimongal, Subalong, Tamabil, Teiabil
20. Akhaura Terrace	42	Bagadi, Dariapur, Latumura, Nidarabad, Pattan, Rupa, Sibna, Simrail
Total	465	

Source SRDI (2010)

Table 9.2 The extent and parent material types of the 20 physiographic units

Item number	Physiographic units	Parent material types	Area (ha, estimated)
1.	Old Himalayan Piedmont Plain	Himalayan piedmont plain	400,800
	Lower Purnabhaba Floodplain		
3.	Tista Meander Floodplain	Tista River alluvium	1,209,800
4.	Karotoa–Bangali Floodplain	Karotoa–Bangali alluvium	257,200
5.	Lower Atrai Basin	Atrai River alluvium	98,000
6.	Brahmaputra Floodplain	Brahmaputra River alluvium	1,634,400
		Jamuna River alluvium	
7.	Ganges River Floodplain	Ganges River alluvium	2,450,800
		Mahananda River alluvium	
8.	Ganges Tidal Floodplain	Ganges tidal alluvium	1,706,600
9.	Gopalganj–Khulna Beel	Peat	2,24,700
10.	Arial Beel	Ganges River alluvium	14,400
6.	Meghna River Floodplain	Meghna River alluvium	246,400
7.	Meghna Estuarine Floodplain	Meghna estuarine alluvium	1,700,900
8.	Surma–Kushyara Floodplain	Surma–Kushyara alluvium	462,200
		Eastern River alluvium	
9.	Northern and Eastern Piedmont Plains	Eastern piedmont alluvium	403,800
10.	Chittagong Coastal Plains	Chittagong coastal alluvium	372,000
11.	St Martin's Coral Island		
12.	Barind Tract	Madhupur clay and Madhupur clay alluvium	1,208,424
13.	Madhupur Tract		
14.	Akhaura Terrace		
15.	Northern and Eastern Hills	Tertiary rocks	1,817,172
Total	20	20	14,480,000

Source FAO-UNDP (1988)

Table 9.3 List of the soil series of Bangladesh as per the RSS report with their extent, parent materials, and classification in the USDA soil subgroups

Soil series	Area (ha)	Parent material	USDA soil subgroup
Adatala	623	Tista river alluvium	Aeric Albaquepts
Ajmiriganj	28,696	Surma–Kushiara alluvium	Typic Haplaquepts
Alsis	659	Himalayan piedmont alluvium	Fluvaquentic Hamaquepts
Amgaon	18,274	Himalayan piedmont alluvium	Aeric Haplaquepts
Amjhupi	111,283	Ganges River alluvium	Aeric Haplaquepts
Amnura	180,804	Madhupur clay	Aeric Albaquept
Arial	22,076	Ganges River alluvium	Aeric Fluvaquentic Haplaquepts
Arunbari	666	Tista river alluvium	Udic Ustochrepts
Asasuni	44,675	Ganges tidal alluvium	Typic Haplaquepts
Astagram	14,855	Meghna estuarine alluvium	Aeric Haplaquepts
Atahar	18,067	Madhupur clay	Aeric Albaquepts
Atiagram	3,121	Himalayan piedmont alluvium	Typic Haplaquepts
Atwari	36,065	Himalayan piedmont alluvium	Typic Haplumbrepts
Ayda	1,838	Meghna clay alluvium	Aeric Albaquepts
Badarkhali	7,108	Chittagong coastal alluvium	Typic Sulphaquepts
Bagadi	202	Eastern piedmont alluvium	Aeric Haplaquepts
Baghda	1,361	Meghna River alluvium	Typic Haplaquolls
Bahubal	3,984	Surma–Kushiara alluvium	Typic Haplaquepts
Bajoa	30,150	Ganges River alluvium	Typic Haplaquepts
Bajora	2,793	Meghna estuarine alluvium	Typic Haplaquepts
Bajra	3,051	Tista River alluvium	Aeric Fluvaquents
Bajuka	11	Surma–Kushiara alluvium	Typic Fluvaquents
Balaganj	23,301	Surma–Kushiara alluvium	Typic Haplaquepts
Baliadangi	54,982	Himalayan piedmont alluvium	Aquic Dystric Eutrochrepts
Baliakandi	12,322	Ganges River alluvium	Aeric Haplaquepts
Balina	32,597	Brahmaputra River alluvium	Aeric Haplaquepts
Balisira	3,175	Eastern piedmont alluvium	Aeric Haplaquepts
Balua	12,733	Meghna estuarine alluvium	Humic Haplaquepts
Bamai	1,038	Surma–Kushiara alluvium	Aeric Haplaquepts
Bancharampur	2,899	Meghna River alluvium	Aeric Haplaquepts
Bangaon	813	Ganges River alluvium	Typic Psammaquents
Banyachung	6,338	Meghna estuarine alluvium	Aeric Haplaquepts
Barabakia	5,524	Chittagong coastal alluvium	Sulphic Haplaquepts
Barar char	10,119	Brahmaputra River alluvium	Typic Fluvaquents
Barhatta	810	Brahmaputra River alluvium	Humic Haplaquepts
Barisal	384,305	Ganges River alluvium	Typic Haplaquepts
Barkal	24,117	Tertiary rocks	Dystric Eutrochrepts
Barlekha	65,087	Tertiary rocks	Plinthic Haplustults
Barura	44,237	Meghna estuarine alluvium	Aeric Haplaquepts
Basail	660	Ganges River alluvium	Aeric Haplaquepts
Bashanda	1,704	Minor eastern rivers alluvium	Aquic Dystric Eutrochrepts
Batazor	6,513	Meghna estuarine alluvium	Aeric Haplaquepts
Batra	94,409	Ganges River alluvium	Aeric Haplaquepts

(continued)

Table 9.3 (continued)

Soil series	Area (ha)	Parent material	USDA soil subgroup
Beach sand	9,265	Chittagong coastal alluvium	Typic Fluvaquents
Beani bazar	1,810	Tertiary rocks	Typic Fluvaquents
Belabo	40,069	Madhupur clay	Plinthic Haplustults
Belaichari	46,744	Tertiary rocks	Lithic Udic Ustochrepts
Belna	1,425	Meghna River alluvium	Typic Haplaquepts
Belonia	12,664	Minor eastern rivers alluvium	Aeric Haplaquepts
Benapol	17,782	Ganges River alluvium	Aeric Haplaquepts
Benghar	4,262	Himalayan piedmont alluvium	Typic Humaquepts
Beola	4,719	Atria River alluvium	Aeric Haplaquepts
Bera	373	Ganges River alluvium	Aeric Haplaquepts
Betagi	1,693	Meghna River alluvium	Typic Fluvaquents
Betbaria	2,593	Meghna estuarine alluvium	Aeric Haplaquolls
Bhajanpur	3,107	Himalayan piedmont alluvium	Typic Humaquepts
Bharella	16,222	Eastern piedmont alluvium	Typic Humaquepts
Bhatiari	1,266	Chittagong coastal alluvium	Typic Fluvaquents
Bhatpara	5,604	Madhupur clay	Typic Ustochrepts
Bhimpur	5,388	Tista River alluvium	Aeric Haplaquepts
Bhola	28,943	Ganges tidal alluvium	Aeric Haplaquepts
Bhugai	1,859	Eastern piedmont alluvium	Udic Ustochrepts
Bhusna	1,751	Eastern piedmont alluvium	Aeric Haplaquepts
Bhutlia	320	Atria River alluvium	Aeric Haplaquents
Bijipur	31,482	Eastern piedmont alluvium	Typic Haplaquepts
Binsara	7,383	Madhupur clay	Aeric Albaquepts
Birganj	10,067	Himalayan piedmont alluvium	Udic Ustochrepts
Birinchi	38	Minor eastern rivers alluvium	Aeric Haplaquepts
Biruli	2,193	Minor eastern rivers alluvium	Aquic Udifluvents
Bonarpara	21,752	Tista River alluvium	Aeric Haplaquepts
Borda	27,243	Meghna River alluvium	Typic Haplaquepts
Bulako	229	Tertiary rocks	Typic Ustipsammaents
Burichang	67,014	Meghna estuarine alluvium	Aeric Haplaquepts
Chakaria	4,859	Chittagong coastal alluvium	Sulphic Fluvaquents
Chakla	1,152	Eastern piedmont alluvium	Typic Haplaquepts
Chandina	8,680	Meghna estuarine alluvium	Aeric Haplaquepts
Chandpur	6,876	Meghna River alluvium	Aeric Haplaquepts
Chandra	46,450	Madhupur clay	Albic Paleaquulfs
Chandraganj	19,819	Meghna estuarine alluvium	Aeric Haplaquepts
Chandraghona	559	Minor eastern rivers alluvium	Aeric Haplaquepts
Channel complex	9,917	Tista River alluvium	Typic Fluvaquents
Charkai	11,286	Madhupur clay alluvium	Aeric Haplaquepts
Charland	50,163	Ganges River alluvium	Aeric Fluvaquents
Charol	5,762	Himalayan piedmont alluvium	Aeric Haplaquepts
Cheora	140	Minor eastern rivers alluvium	Aeric Haplaquepts
Cheringa	8,506	Chittagong coastal alluvium	Typic Sulfaquepts
Chhatak	1,098	Tertiary rocks	Typic Dystrochrepts

(continued)

Table 9.3 (continued)

Soil series	Area (ha)	Parent material	USDA soil subgroup
Chhiata	11,070	Madhupur clay	Aeric Albaquepts
Chhilania	1,861	Minor eastern rivers alluvium	Aeric Haplaquepts
Chilmari	28,625	Tista River alluvium	Aeric Haplaquepts
Chinakuri	16,764	Eastern piedmont alluvium	Typic Haplaquents
Chinaura	185	Tertiary rocks	Umbric Dystrochrepts
Chormara	1,792	Karatoya–Bangali alluvium	Aeric Haplaquepts
Choumaka	789	Madhupur clay alluvium	Typic Haplaquepts
Crarse tex. Ga all	12,266	Ganges River alluvium	Typic Psammaquents
Companyganj	2,027	Minor eastern rivers alluvium	Aeric Haplaquepts
Coral beach sand	492	Chittagong coastal alluvium	Typic Psammaquents
Dacope	9,270	Ganges tidal alluvium	Typic Haplaquepts
Dagan	934	Minor eastern rivers alluvium	Aeric Haplaquepts
Dakatia	3,640	Minor eastern rivers alluvium	Aeric Haplaquepts
Dakhinpara	16	Chittagong coastal alluvium	Typic Fluvaquents
Dantmara	1,211	Tertiary rocks	Petroferic Haplumbrepts
Dariapur	100	Eastern piedmont alluvium	Thapto- Histic Haplaquepts
Darsana	94,577	Ganges River alluvium	Typic Eutrochrepts
Daspara	6,518	Jamuna River alluvium	Typic Fluvaquents
Daulatpur	11,139	Ganges River alluvium	Typic Humaquepts
Debidwar	77,562	Meghna estuarine alluvium	Aeric Haplaquepts
Demra	3,296	Madhupur clay	Typic Haplaquepts
Deopara	2,420	Atria River alluvium	Typic Haplaquepts
Dhalat	344	Ganges River alluvium	Aeric Haplaquepts
Dhamrai	117,576	Brahmaputra River alluvium	Aeric Haplaquepts
Dhamti	44,594	Meghna estuarine alluvium	Aeric Haplaquepts
Dharmapasha	1,952	Eastern piedmont alluvium	Aeric Haplaquepts
Dhum	5,514	Tertiary rocks	Dystric Eutrochrepts
Dhunat	7,747	Tista River alluvium	Aeric Haplaquepts
Dhurung	3,011	Chittagong coastal alluvium	Sulphic Haplaquepts
Diarkandi	1,074	Brahmaputra River alluvium	Typic Haplaquepts
Digli	17,821	Tista River alluvium	Typic Haplaquepts
Dimla	8,320	Tista River alluvium	Aeric Psammaquents
Dirai	28,040	Surma–Kushiara alluvium	Thapto- Histic Haplaquepts
Dohali	40,662	Tista River alluvium	Aeric Haplaquepts
Dolu	2,802	Minor eastern rivers alluvium	Typic Fluvaquents
Domar	47,504	Tista River alluvium	Umbric Ustochrepts
Dubalia	4,312	Ganges River alluvium	Aquic Udifluvents
Dudnai	3,814	Madhupur clay	Aquic Ustochrepts
Dulai	3,406	Ganges River alluvium	Aeric Fluvaquents
Dulalpur	1,528	Brahmaputra River alluvium	Aeric Fluvaquentic Haplaquepts
Dumuria	29,609	Ganges tidal alluvium	Aeric Haplaquepts
Durgapur	784	Eastern piedmont alluvium	Humic Haplaquepts
Ekdala	65,447	Madhupur clay	Aeric Albaquepts
Elachur	7,646	Ganges tidal alluvium	Thapto- Histic Humaquepts

(continued)

Table 9.3 (continued)

Soil series	Area (ha)	Parent material	USDA soil subgroup
Elanga	6,933	Atria River alluvium	Typic Fluvaquents
Farabari	63,042	Himalayan piedmont alluvium	Aeric Haplaquepts
Faridganj	6,139	Meghna River alluvium	Aeric Haplaquepts
Fatehpur	4,135	Eastern piedmont alluvium	Typic Haplaquepts
Feni	4,223	Minor eastern rivers alluvium	Aeric Haplaquepts
Fine text. Ga all	15,830	Ganges River alluvium	Aeric Fluvaquents
Fuldi	30,894	Meghna River alluvium	Aeric Haplaquepts
Gabtali	61,814	Tista River alluvium	Typic Haplaquepts
Gahira	3,662	Chittagong coastal alluvium	Typic Haplaquepts
Gangachara	253,756	Tista River alluvium	Typic Haplaquepts
Gangni	101,255	Ganges River alluvium	Aeric Haplaquepts
Garuri	193,649	Ganges River alluvium	Aeric Haplaquepts
Gaurndi	2,616	Ganges River alluvium	Vertic Haplaquepts
Gayra	6,444	Tista River alluvium	Aeric Haplaquepts
Gazni	782	Tertiary rocks	Ultic Dystrochrepts
Genda	829	Madhupur clay	Aeric Haplaquepts
Gerua	44,825	Madhupur clay	Aquic Haplustulfs
Ghagra	87	Tertiary rocks	Dystric Eutrochrepts
Ghatail	227,016	Brahmaputra River alluvium	Aeric Haplaquepts
Ghazipura	241	Madhupur clay alluvium	Aeric Fluvaquentic Haplaquents
Ghior	239,788	Ganges River alluvium	Aeric Haplaquepts
Ghosgaon	2,036	Tertiary rocks	Ultic Ustrochrepts
Goalgram	394	Karatoya–Bangali alluvium	Typic Haplaquepts
Godnail	16,430	Meghna estuarine alluvium	Aeric Fluvaquentic Haplaquepts
Gomastapur	7,247	Tista River alluvium	Aeric Haplaquepts
Gopalpur	206,509	Ganges River alluvium	Typic Eutrochrepts
Gorargaon	11,093	Brahmaputra River alluvium	Typic Haplaquepts
Gouripur	3,986	Brahmaputra River alluvium	Typic Haplaquepts
Goyainghat	93,856	Surma–Kushiara alluvium	Typic Haplaquepts
Guldaha	701	Tista River alluvium	Aeric Haplaquepts
Gulta	36,018	Madhupur clay	Aeric Albaquepts
Gumti	3,791	Minor eastern rivers alluvium	Aeric Haplaquents
Gundum	38	Chittagong coastal alluvium	Typic Sulfaquepts
Hakaluki	4,953	Peat	Fibrist, Hemists
Halda	10,379	Minor eastern rivers alluvium	Typic Haplaquepts
Halti	14,406	Atria River alluvium	Typic Haplaquepts
Hamidpur	2,569	Madhupur clay alluvium	Aeric Haplaquepts
Harbang	794	Chittagong coastal alluvium	Typic Haplaquepts
Harta	44,273	Peat	Thapto- Histic Haplaquepts
Hasnabad	4,238	Tista River alluvium	Aeric Haplaquepts
Hatiya	63,749	Meghna estuarine alluvium	Aeric Fluvaquents
Hazaribak	119,151	Tertiary rocks	Udic Ustochrepts
Hiakhu	3,519	Tertiary rocks	Plinthic Paleustults

(continued)

Table 9.3 (continued)

Soil series	Area (ha)	Parent material	USDA soil subgroup
Hijla	16,091	Ganges River alluvium	Aeric Haplaquepts
Hisabia	2,037	Himalayan piedmont alluvium	Aeric Haplaquepts
Hoanak	491	Eastern piedmont alluvium	Typic Fluvaquentss
Hogla	8,895	Ganges tidal alluvium	Thapto- Histic Haplaquepts
Homna	9,902	Meghna River alluvium	Aeric Haplaquepts
Horgathi	772	Karatoya–Bangali alluvium	Typic Psammaquents
Hulibari	3,232	Atria River alluvium	Aeric Haplaquepts
Humayunpur	266	Meghna estuarine alluvium	Typic Haplaquepts
Ichamati	59	Jamuna River alluvium	Aeric Fluvaquents
Ikram	4,727	Meghna estuarine alluvium	Aeric Haplaquepts
Ilsa	29,408	Meghna estuarine alluvium	Typic Haplaquepts
Imadpur	12,030	Tista River alluvium	Aeric Haplaquepts
Inathganj	1,066	Surma–Kushiara alluvium	Typic Haplaquepts
Indrail	2,281	Himalayan piedmont alluvium	Aeric Haplaquepts
Ishurdi	211,359	Ganges River alluvium	Aeric Haplaquepts
Ishwarganj	1,360	Brahmaputra River alluvium	Aeric Haplaquepts
Itakhola	7,755	Eastern piedmont alluvium	Typic Haplaquepts
Jaflong	4,343	Eastern piedmont alluvium	Typic Dystrochrepts
Jagdal	12,921	Himalayan piedmont alluvium	Aquic Eutrochrepts
Jaldhaka	2,889	Tista River alluvium	Typic Haplaquents
Jaldi	14,287	Tertiary rocks	Dystric Eutrochrepts
Jaligang	8,510	Eastern piedmont alluvium	Aeric Haplaquepts
Jalkundi	36,665	Meghna estuarine alluvium	Aeric Fluvaquentic Haplaquepts
Jamalpur	591	Brahmaputra River alluvium	Aeric Haplaquents
Jamtail	4,930	Karatoya–Bangali alluvium	Aeric Haplaquents
Jamun	60,148	Tista River alluvium	Aeric Haplaquents
Jaonia	16,228	Atria River alluvium	Typic Haplaquepts
Jatrabari	2,067	Madhupur clay	Typic Haplaquepts
Jayanti	3,186	Ganges River alluvium	Aeric Haplaquepts
Jhalakati	117,712	Ganges River alluvium	Typic Haplaquepts
Jhikra	1,524	Madhupur clay	Typic Ustochrepts
Jhilima	8,593	Madhupur clay alluvium	Aeric Albaquepts
Jhinaighati	5,392	Eastern piedmont alluvium	Aeric Haplaquepts
Jibanpur	185	Tertiary rocks	Typic Dystrochrepts
Jinjira	109	Chittagong coastal alluvium	Typic Ustipsammaents
Juri	2,035	Peat	Fibrist, Hemists
Kachna	4,589	Tista River alluvium	Typic Haplaquepts
Kadipur	7,758	Surma–Kushiara alluvium	Typic Haplaquepts
Kahalu	12,477	Madhupur clay alluvium	Aeric Haplaquepts
Kaipara	8,884	Eastern piedmont alluvium	Aeric Haplaquepts
Kajla	25,298	Karatoya–Bangali alluvium	Fluvaquentic Haplaquepts
Kakina	1,180	Tista River alluvium	Typic Haplaquepts
Kakmari	5291	Ganges tidal alluvium	Thapto- Histic Haplaquepts

(continued)

Table 9.3 (continued)

Soil series	Area (ha)	Parent material	USDA soil subgroup
Kalapani	11,838	Tertiary rocks	Humic Hapludults
Kalatia	2,596	Meghna River alluvium	Typic Fluvaquents
Kalbader	8,553	Ganges River alluvium	Aeric Haplaquepts
Kalma	44,644	Madhupur clay alluvium	Aeric Albaquepts
Kamalakati	30,487	Ganges tidal alluvium	Typic Sulphaquepts
Kamarkhanda	15,149	Tista River alluvium	Aeric Haplaquepts
Kamuri	821	Tertiary rocks	Rhodic Paleustults
Kanairghat	121,861	Surma–Kushiara alluvium	Typic Haplaquepts
Kanchanpur	6,568	Brahmaputra River alluvium	Aeric Haplaquepts
Kangsa	7,035	Eastern piedmont alluvium	Aeric Haplaquepts
Kanil	1,609	Atria River alluvium	Typic Haplaquepts
Kankrachari	44,495	Tertiary rocks	Dystric Eutrochrepts
Kaptai	486,493	Tertiary rocks	Typic Haplustults
Karail	14,379	Madhupur clay	Cumulic Lithic Humaquepts
Karerhat	309	Tertiary rocks	Aquic Dystrochrepts
Karnaphuli	21,665	Tertiary rocks	Fluvaquentic Ustochrepts
Kashimpur	9,634	Madhupur clay	Rhodic Haplustults
Kasiani	9,774	Ganges River alluvium	Aeric Haplaquepts
Kassalong	838	Tertiary rocks	Udic Ustochrepts
Kathuli	7,042	Ganges River alluvium	Typic Eutrochrepts
Katra	6,129	Ganges River alluvium	Typic Fluvaquents
Kaunia	118,195	Tista River alluvium	Typic Haplaquepts
Kendua	11,189	Brahmaputra River alluvium	Aeric Haplaquepts
Khadimnagar	20,656	Tertiary rocks	Typic Dystrochrepts
Khaira	219	Brahmaputra River alluvium	Aeric Haplaquepts
Khaler char	5,063	Brahmaputra River alluvium	Typic Fluvaquents
Kharrera	932	Tertiary rocks	Plinthic Haplustults
Khasgaon	9,725	Surma–Kushiara alluvium	Typic Haplaquepts
Khilgaon	38,393	Madhupur clay alluvium	Typic Haplaquepts
Khiram	4,689	Tertiary rocks	Plinthic Haplustults
Kiranchi	18,048	Ganges River alluvium	Aeric Haplaquepts
Kirtankhola	566	Madhupur clay alluvium	Aquic Dystrochrepts
Koladi	2,411	Ganges River alluvium	Typic Haplaquepts
Kotbari	743	Eastern piedmont alluvium	Typic Udifluvents
Kotwalipara	15,084	Meghna estuarine alluvium	Typic Haplaquepts
Kulaura	10,045	Tertiary rocks	Typic Haplustalfs
Kumarkhali	1,671	Ganges River alluvium	Typic Haplaquepts
Kumira	12,313	Chittagong coastal alluvium	Typic Haplaquepts
Kusiyara	10,374	Surma–Kushiara alluvium	Typic Fluvaquents
Kuslia	1,583	Ganges River alluvium	Typic Eutrochrepts
Kutubdia	11,312	Chittagong coastal alluvium	Sulphic Haplaquepts
Lakhaichara	1,612	Tertiary rocks	Typic Dystrochrepts
Lakhipur	11,756	Himalayan piedmont alluvium	Typic Haplumbrepts
Lalmai	890	Tertiary rocks	Typic Paleustults

(continued)

Table 9.3 (continued)

Soil series	Area (ha)	Parent material	USDA soil subgroup
Lalor	363	Atria River alluvium	Aeric Haplaquents
Lama	9,186	Tertiary rocks	Dystric Eutrochrepts
Lashkara	19,834	Himalayan piedmont alluvium	Typic Haplaquepts
Latumura	36	Tertiary rocks	Aquic Dystrochrepts
Lauta	123,482	Madhupur clay	Aeric Albaquepts
Lokdeo	137,999	Brahmaputra River alluvium	Aeric Haplaquepts
Madhabpur	26,431	Meghna estuarine alluvium	Aeric Haplaquepts
Madhaynagar	8,568	Surma–Kushiara alluvium	Typic Haplaquepts
Madna	5,350	Meghna River alluvium	Aeric Haplaquepts
Magra	19,132	Meghna estuarine alluvium	Typic Haplaquepts
Mahespur	2,892	Ganges River alluvium	Typic Haplaquepts
Mainam	11,307	Atria River alluvium	Aeric Haplaquepts
Majpara	6,215	Tista River alluvium	Typic Haplaquepts
Mlanchi	15,184	Tista River alluvium	Aeric Haplaquents
Maldaha	6,781	Karatoya–Bangali alluvium	Typic Fluvaquents
Mallika	299	Atria River alluvium	Aeric Haplaquepts
Manda	22,583	Tista River alluvium	Aeric Fluvaquents
Manikandi	1,360	Minor eastern rivers alluvium	Typic Haplaquepts
Manikdi	3,274	Ganges River alluvium	Aeric Fluvaquents
Manu	57,129	Eastern piedmont alluvium	Typic Haplaquepts
Maria	5,173	Ganges River alluvium	Aeric Haplaquepts
Marisi	2,409	Eastern piedmont alluvium	Udic Ustochrepts
Markuli	1,820	Eastern piedmont alluvium	Aeric Haplaquepts
Matia	10,199	Karatoya–Bangali alluvium	Typic Haplaquepts
Matlab	6,335	Meghna River alluvium	Aeric Haplaquepts
Med. Tex. Gang. Allu.	50,395	Ganges River alluvium	Aeric Fluvaquents
Mehendiganj	43,047	Ganges River alluvium	Aeric Haplaquepts
Melandaha	8,729	Brahmaputra River alluvium	Aeric Haplaquepts
Menanagar	20,411	Tista River alluvium	Typic Fluvaquents
Mirpur	47,767	Ganges River alluvium	Typic Eutrochrepts
Mirsarai	37,549	Eastern Piedmont alluvium	Typic Haplaquepts
Moghachari	15,275	Minor eastern rivers alluvium	Aeric Haplaquents
Mohanganj	4,930	Brahmaputra River alluvium	Haplic Hydraquents
Monakhali	2,940	Chittagong coastal alluvium	Aeric Psammaquents
Mud	56,445	Meghna estuarine alluvium	Typic Fluvaquents
Muhari	5,809	Minor eastern rivers alluvium	Aeric Haplaquepts
Muladi	35,036	Ganges River alluvium	Aeric Haplaquepts
Munsumi	475	Karatoya–Bangali alluvium	Aeric Haplaquepts
Muradnagar	3,161	Minor eastern rivers alluvium	Aeric Haplaquepts
Musapur	8,518	Meghna estuarine alluvium	Aeric Haplaquepts
Nabinagar	5,601	Minor eastern rivers alluvium	Mollic Fluvaquents
Nachol	20,810	Madhupur clay alluvium	Aeric Albaquepts
Naga	10,961	Madhupur clay alluvium	Fluvaquentic Haplaquepts
Nagarbari	2,287	Jamuna River alluvium	Typic Psammaquents

(continued)

Table 9.3 (continued)

Soil series	Area (ha)	Parent material	USDA soil subgroup
Nakla	12,812	Brahmaputra River alluvium	Aquic Eutrochrepts
Nalchitti	41,257	Ganges tidal alluvium	Aeric Haplaquepts
Naldanga	347	Tista River alluvium	Haplic Hydraquents
Nalitabari	25,238	Eastern piedmont alluvium	Aeric Haplaquepts
Nalua	42,101	Tertiary rocks	Plinthic Haplustults
Nandail	7,442	Brahmaputra River alluvium	Aeric Haplaquepts
Nandigram	2,691	Himalayan piedmont alluvium	Fluvaquentic Humaquepts
Naraibag	53,681	Meghna estuarine alluvium	Aeric Haplaquepts
Narail	12,931	Ganges River alluvium	Thapto- Histic Haplaquepts
Naria	456	Ganges River alluvium	Aeric Fluvaquents
Narikeldia	171	Chittagong coastal alluvium	Typic Psammaquents
Nasirnagar	5,748	Minor eastern rivers alluvium	Mollic Fluvaquents
Nayabati	942	Himalayan piedmont alluvium	Typic Haplumbrepts
Nayanpur	13	Madhupur clay alluvium	Aquic Dystrochrepts
Nekmarad	3,425	Himalayan piedmont alluvium	Typic Haplaquepts
Nahila	1,002	Chittagong coastal alluvium	Typic Sulphaquepts
Nidarabad	2,258	Tertiary rocks	Plinthic Haplustults
Nijhuri	87,850	Madhupur clay	Aeric Albaquepts
Nilkamal	63,942	Meghna estuarine alluvium	Typic Haplaquepts
Noadda	33,636	Madhupur clay	Typic Paleustalfs
Noakhali	18,597	Meghna estuarine alluvium	Arents
Noapara	7,693	Chittagong coastal alluvium	Typic Haplaquepts
Nonachari	2,794	Chittagong coastal alluvium	Typic Fluvaquents
Nunni	13,614	Chittagong coastal alluvium	Aeric Psammaquents
Olipur	627	Eastern piedmont alluvium	Typic Fluvaquents
Pagla	6,611	Ganges River alluvium	Aeric Fluvaquentic Haplaquepts
Pahartali	36,622	Eastern piedmont alluvium	Typic Haplaquepts
Paikpara	25,467	Meghna River alluvium	Aeric Haplaquepts
Pakuria	135,998	Ganges River alluvium	Aeric Haplaquepts
Palang	1,072	Meghna estuarine alluvium	Mollic Haplaquepts
Palashbari	40,849	Tista alluvium	Aquic Dystric Eutrochrepts
Palashtala	764	Eastern piedmont alluvium	Typic Fluvaquents
Pamol	5,965	Himalayan piedmont alluvium	Dystric Eutrochrepts
Panchagarh	10,704	Himalayan piedmont alluvium	Typic Haplumbrepts
Panchlais	3,315	Minor eastern rivers alluvium	Aeric Haplaquepts
Pangsa	1,685	Ganges River alluvium	Aeric Fluvaquents
Parsuram	119	Minor eastern rivers alluvium	Aeric Haplaquepts
Patenga	15,877	Chittagong coastal alluvium	Typic Haplaquepts
Patharghata	674	Ganges River alluvium	Aeric Haplaquepts
Pattan	2,037	Tertiary rocks	Typic Paleustults
Pauali	8,386	Madhupur clay alluvium	Aeric Albaquepts
Payati	5,661	Madhupur clay alluvium	Aeric Haplaquents
Payna	1,609	Atria River alluvium	Typic Haplaquepts
Paysa	24,113	Meghna estuarine alluvium	Typic Haplaquepst

(continued)

Table 9.3 (continued)

Soil series	Area (ha)	Parent material	USDA soil subgroup
Phagu	308,980	Surma–Kushiara alluvium	Typic Haplaquepts
Phulpur	1,250	Brahmaputra River alluvium	Typic Ustipsammaents
Piprul	907	Atria River alluvium	Typic Haplaquepts
Pirgachha	86,030	Himalayan piedmont alluvium	Udic Ustochrepts
Pirojpur	118,691	Ganges River alluvium	Thapto- Histic Haplaquepst
Poradi	3,627	Karatoya–Bangali alluvium	Aeric Haplaquents
Pritimpasa	70,844	Eastern piedmont alluvium	Typic Haplaquepts
Puna	4,744	Madhupur clay alluvium	Aeric Albaquepts
Purbabagh	1,206	Eastern piedmont alluvium	Thapto- Histic Haplaquepts
Puspakati	610	Ganges River alluvium	Aquic Eutrochrepts
Rajair	18,412	Peat	Histosols
Rajas an	521	Brahmaputra River alluvium	Aeric Fluvaquents
Ramdia	11,569	Ganges River alluvium	Typic Haplaquepts
Ramgarh	25444	Tertiary rocks	Humic Hapludults
Ramgati	209,913	Meghna estuarine alluvium	Typic Haplaquepts
Ramnagar	15,642	Eastern piedmont alluvium	Aeric Haplaquepts
Rampal	6,190	Brahmaputra River alluvium	Arents
Rangamati	38,873	Tertiary rocks	Typic Hapludults
Rangapani	14,343	Tertiary rocks	Ultic Dystrochrepts
Rangari	1,718	Eastern piedmont alluvium	Aeric Haplaquepts
Rangunia	4,990	Minor eastern rivers alluvium	Typic Haplaquepts
Ranisankail	34,872	Himalayan piedmont alluvium	Udic Ustochrepts
Rankhiang	60,531	Tertiary rocks	Udic Ustochrepts
Raojan	30,164	Chittagong coastal alluvium	Typic Haplaquepts
Rathuria	13,474	Ganges River alluvium	Aeric Fluvaquentic Haplaquepts
Ratna	4,261	Eastern piedmont alluvium	Typic Dystrochrepts
Rauli	2,956	Surma–Kushiara alluvium	Aeric Haplaquepts
Rayna	3,395	Ganges River alluvium	Aquic Udifluvents
Richi	38,247	Meghna estuarine alluvium	Humic Haplaquepts
Ruhea	13,326	Himalayan piedmont alluvium	Typic Haplumbrepts
Ruma	3,812	Minor eastern rivers alluvium	Dystric Eutrochrepts
Rupa	1,231	Eastern piedmont alluvium	Aeric Haplaquepts
Ruppur	6,434	Ganges River alluvium	Aquic Eutrochrepts
Sabhar Bazar	83,287	Brahmaputra River alluvium	Aeric Fluvaquentic Haplaquepts
Sachna	7,131	Eastern piedmont alluvium	Typic Haplaquepts
Safapur	4,511	Atria River alluvium	Typic Haplaquepts
Sahaji Bazar	6,242	Eastern piedmont alluvium	Typic Haplaquepts
Sahapur	19,219	Madhupur clay	Typic Albaquepts
Sajek	5,870	Tertiary rocks	Typic Dystrochrepts
Salandar	11,484	Himalayan Piedmont alluvium	Udic Ustochrepts
Salban	19,324	Tertiary rocks	Typic Dystrochrepts
Salna	10,633	Madhupur clay	Plinthic Paleustults
Saluka	1,910	Tista River alluvium	Typic Haplaquepts

(continued)

Table 9.3 (continued)

Soil series	Area (ha)	Parent material	USDA soil subgroup
Sandwip	6,238	Meghna estuarine alluvium	Aeric Haplaquepts
Sandy Brahm All	26,546	Brahmaputra River alluvium	Typic Psammaquents
Sandy Ganges All	12,511	Ganges River alluvium	Typic Psammaquents
Sandy Jamuna All	51,705	Jamuna River alluvium	Typic Psammaquents
Sandy Karatoa All	872	Karatoya–Bangali alluvium	Typic Psammaquents
Sandy Meghna All	1,648	Meghna River alluvium	Typic Psammaquents
Sandy Tista All	2,811	Tista River alluvium	Typic Psammaquents
Sangar	5,035	Meghna estuarine alluvium	Aeric Haplaquepts
Sankochail	1,824	Tertiary rocks	Aquic Haplustults
Santhia	84,235	Ganges River alluvium	Typic Haplaquepts
Sara	249,798	Ganges River alluvium	Aquic Eutrochrepts
Sarail	595	Minor eastern rivers alluvium	Thapto- Histic Fluvaquents
Sarala	2,508	Tista River alluvium	Aeric Haplaquepts
Sarta	11,653	Eastern piedmont alluvium	Typic Haplaquepts
Satbaria	3,232	Atria River alluvium	Typic Haplaquepts
Satgaon	722	Peat	Histosols
Satla	48,505	Peat	Histosols
Satnal	5,363	Meghna River alluvium	Aeric Haplaquepts
Satoya	447	Himalayan Piedmont alluvium	Aeric Haplaquepts
Sayek	7,965	Madhupur clay	Typic Paleustults
Selapur	851	Eastern Piedmont alluvium	Typic Haplaquept
Serkol	907	Atria River alluvium	Typic Haplaquepts
Shaghatta	12,074	Tista River alluvium	Aeric Fluvaquents
Shaktola	470	Minor eastern rivers alluvium	Typic Haplaquepts
Shamganj	2,043	Brahmaputra River alluvium	Aeric Haplaquepts
Shariakandi	6,886	Tista River alluvium	Aeric Haplaquepts
Sherpur	36,678	Brahmaputra River alluvium	Aquic Eutrochrepts
Sibna	630	Tertiary rocks	Typic Paleustults
Siddhirganj	12,419	Brahmaputra River alluvium	Aeric Haplaquepts
Silaikuti	6,863	Himalayan piedmont alluvium	Patchic Haplumbrept s
Silmandi	200,610	Brahmaputra River alluvium	Aeric Haplaquepts
Silty Brahm All	30,717	Brahmaputra River alluvium	Typic Fluvaquents
Silty Ganges All	39,532	Ganges River alluvium	Aeric Haplaquents
Silty Jamuna All	79,275	Jamuna River alluvium	Typic Fluvaquents
Silty Karatoa All	530	Karatoya River alluvium	Typic Fluvaquents
Silty Mahananda All	91	Mahananda River alluvium	Typic Fluvaquents
Silty Meghna All	1,600	Meghna River alluvium	Typic Fluvaquents
Silty Surkus All	117	Surma–Kushiara alluvium	Typic Haplaquepts
Silty Tista All	24,669	Tista River alluvium	Typic Haplaquepts
Simrail	78	Tertiary rocks	Aeric Paleaquults
Singair	36,270	Brahmaputra River alluvium	Aquic Fluvaquentic Haplaquepts
Sitakund	9,628	Tertiary rocks	Lithic Ustochrepts
Someswari	1,827	Eastern piedmont alluvium	Typic Fluvaquents

(continued)

Table 9.3 (continued)

Soil series	Area (ha)	Parent material	USDA soil subgroup
Sonatala	217,097	Brahmaputra River alluvium	Aeric Haplaquepts
Sribardi	3,623	Eastern piedmont alluvium	Typic Fluvaquents
Srighar	1,920	Surma–Kushiara alluvium	Typic Haplaquepts
Srikola	4,223	Karatoya–Bangali alluvium	Aeric Fluvaquents
Srimangal	17,371	Tertiary rocks	Plinthic Haplustults
Srirampur	47,056	Tista River alluvium	Typic Haplaquepts
Subalong	25,986	Tertiary rocks	Dystric Eutrochrepts
Subhapur	12,981	Eastern piedmont alluvium	Aeric Haplaquepts
Sujanagar	1,526	Ganges River alluvium	Aeric Haplaquepts
Sukdebpur	540	Ganges River alluvium	Aquic Eutrochrepts
Sulla	56,183	Surma–Kushiara alluvium	Typic Haplaquepts
Susang	66,207	Eastern piedmont alluvium	Typic Haplaquepts
Sutang	848	Eastern piedmont alluvium	Typic Haplaquepts
Swalak	5,488	Eastern piedmont alluvium	Typic Haplaquepts
Sylok	21,176	Eastern piedmont alluvium	Aquic Dystrochrepts
Tahirpur	10,370	Ganges River alluvium	Typic Haplaquepts
Tajpur	1,053	Surma–Kushiara alluvium	Aeric Haplaquepts
Tamabil	16,324	Tertiary rocks	Typic Haplaquepts
Tarakanda	4,290	Brahmaputra River alluvium	Lithic Ustochrepts
Tarala	604	Himalayan piedmont alluvium	Typic Fluvaquents
Tarapur	447	Eastern piedmont alluvium	Histosols
Taras	44,678	Atria River alluvium	Aeric Haplaquepts
Tarpassa	9,520	Ganges River alluvium	Aeric Haplaquepts
Teghar	28,024	Ganges River alluvium	Aeric Fluvaquentic Haplaquepts
Teiabil	108,011	Tertiary rocks	Aeric Haplaquepts
Tejgaon	106,370	Madhupur clay	Typic Haplustults
Tejkunipara	20,381	Madhupur clay	Rhodic Paleustults
Teknaf	2,726	Chittagong coastal alluvium	Typic Paleustults
Tengar Char	18,641	Meghna River alluvium	Typic Ustipsammaents
Terchibari	101,929	Surma–Kushiara alluvium	Aeric Haplaquepts
Tetla	5,377	Ganges tidal alluvium	Thapto- Histic Fluvaquents
Tetulia	5,187	Himalayan piedmont alluvium	Cumulic Humaquepts
Toppera	92,428	Meghna estuarine alluvium	Aeric Haplaquepts
Titas	1,781	Minor eastern rivers alluvium	Aeric Haplaquepts
Turag	711	Meghna River alluvium	Aeric Fluvaquents
Ukhiya	3,054	Eastern piedmont alluvium	Aeric Haplaquepts
Ulipur	13,961	Tista River alluvium	Aeric Haplaquepts
Ullapara	1,194	Karatoya–Bangali alluvium	Aeric Haplaquepts
Uttargaon	26,255	Himalayan piedmont alluvium	Aeric Haplaquepts
Wazirpur	9,826	Meghna estuarine floodplain	Aeric Haplaquepts
Waikhyang	226	Chittagong coastal alluvium	Sulfic Haplaquepts
Total 476	11,466,913	19	56

The series are arranged alphabetically
Source Hussain et al. 2003

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10 Soil Fertility

Soil fertility is the capability or ability of soils to supply elements essential for plant growth without a toxic concentration of any element. It is the inherent capacity of a soil to supply 14 of the 17 essential nutrient elements to the growing crop. It is the quality of soil that enables it to provide compounds or elements in adequate amounts and in proper balance for the growth of specified plants when other growth factors such as light, moisture, temperature, and the physical conditions of the soils are favorable. So, fertility is the potential nutrient status of a soil to produce crops. As plants have evolved in different climates and on different soils, they have different needs for the essential nutrients and different tolerance to the toxic elements. As such, a soil can be fertile for one plant and at the same time be unfertile for another plant. On the other hand, soil productivity is a measure of the soil's ability to produce a particular crop or sequence of crops under a specified management system.

Bangladesh is a small country with a surface area of little more than 144,000 km^2, or roughly about 14.41 mha, the actual land mass being 10.38 mha (72 % of total area). In the border areas of the east and southeast, there are hills rising over 1,000 m with steep slopes and different terrain that constitute about 2.0 mha. Although the land is not large, the soils are quite varying. So far, 465 soil series have been identified and described. This wide variation in soils is due mainly to the physiography and partly to the microclimatic variation.

Although a majority of the country's soil is developed on alluvial deposits, there are hilly formations, and soils formed under evergreen and/or deciduous forest vegetation. It has been stated earlier that the whole country has been subdivided into 22 physiographic units and the soils are grouped into 19 different categories. Soils developed under each of the physiographic units are identified with them. For example, soils could be Himalayan piedmont soil, hill soils, acid-basin clay soils, calcareous alluvium soil, noncalcareous alluvium soils, peat land soils, mangrove soils, and so on. The topography of the country is variable. The lands are divided into five classes:

1. Highland: Lands where monsoon water does not stagnate. The lands cover the Modhupur jungle in Mymensingh, Bhaoal's gath in Dhaka, the Barind Tract in Rajshahi, the Lalmai area in Comilla, and the Tilla area in Sylhet.
2. Medium land: The lands are uniformly flat faced where water movement could be controlled with the help of ridges. The areas include the northern part of Dhaka and Barisal, part of Mymensingh, the eastern part of Chittagong, Noakhali, and Comilla, and parts of Sylhet, Rajshahi, Dinajpur, Rangpur, Bogra, Pabna, Khulna, Jessore, and Kushtia.
3. Lowland: From 1 to 1.5 m water stands on the land during monsoons which may rise to 3–4 m. Water movement is difficult to control. The lands include areas in parts of Pabna and Faridpur, the southern part of Dhaka, part of Mymensingh, western parts of Comilla and Noakhali, and parts of Sylhet, Bogra, and Khulna.
4. Very low land: The lands consist of haors, beels, canals, and other lowlying areas. The areas cover part of the Sylhet region, and the Kishoreganj and Netrokona districts of the Mymensingh region.
5. Hilly land: These lands extend over the Chittagong Hill Tracts, part of Chittagong, the northern part of Mymensingh, the northeastern parts of Sylhet, the eastern border of Comilla, and the northeastern strip of the Noakhali district.

Due to this variation in soil formation, the land use pattern is also varied. The land use in Bangladesh is controlled by: (1) land types, which are classed as VH, H, MH, ML, to L depending on how many months and how deep they are inundated during the seasonal flooding periods; (2) soil types; (3) local climatic conditions; and (4) the farmers' economic capability (including whether they can pay for the irrigation, high yielding seeds, and requisite agrochemicals). However, most of the lands are either double cropped (47.7 % of the NCA) or single cropped (40.3 % of NCA) with a small proportion of the land given to triple cropping (12.0 % of NCA). Wetland

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rice cultivation occupies the major single-cropped lands. The cropping intensity is almost 177 (176.98 in 2007).

The whole of the country has been divided into 30 agroecological zones (with subzones in many of these zones) considering the diversity of soil types and also the microclimatic variations allowing the growers to select crops on the basis of the soil test results map on AEZ.

The general fertility status of each of these groups is given briefly below.

1. *Old Himalayan Piedmont Plain*: Strongly acidic in topsoil and moderately acidic in subsoils. Organic matter contents are relatively higher than other floodplain areas. The natural fertility of the soil, except the coarse-textured ones, is moderate but well sustained. Soil fertility problems include rapid leaching of N, K, S, Ca, Mg, and B.
2. *Active Tista Floodplain*: Moderately acidic throughout. Organic matter content is low and CEC is medium. Soil fertility level is low to medium.
3. *Tista Meander Floodplain*: Moderately acidic throughout, low in organic matter content on the higher land, but moderate in the lower parts. The fertility level, in general, is low to medium but the status of K and CEC is medium in most places.
4. *Karatoya–Bangali Floodplain*: Moderately acidic throughout. Organic matter content is low in ridges and moderate in basins. General fertility is medium.
5. *Lower Atrai Basin*: Acidic; organic matter, CEC, and status of other essential nutrients are medium, although the level of K is high. Fertility status of soils is moderate.
6. *Lower Punarbhaba Floodplain*: Acidic; organic matter status is medium to high with high CEC. General fertility level is medium with high K status.
7. *Active Brahmaputra–Jamuna Floodplain*: Slightly alkaline; organic matter status is low and fertility status is low to medium. N and P are, in general limiting, whereas the K, S, and Zn status is reasonable.
8. *Young Brahmutra and Jamuna Floodplain*: Neutral to slightly acidic; organic matter content is low in ridges and moderate in basins. Soils are deficient in N, P, and S but the status of K and Zn is reasonable.
9. *Old Brahmaputra Floodplain*: Top soils are moderately acidic although subsoils are neutral. Organic matter content is low in ridges and moderate in basins. The general fertility level is low. P and CEC are medium and K status is low in the highlands and medium in the lowlands.
10. *Active Ganges Floodplain*: Mildly alkaline; organic matter content is low. General fertility level is medium with high CEC but deficient in N and available P and Zn.
11. *High Ganges River Floodplain*: Slightly alkaline; organic matter content in the brown ridge soils is low but higher in the dark grey soils. The general fertility level is low although CEC is medium.
12. *Low Ganges River Floodplain*: Neutral to slightly alkaline; organic matter is low in ridges and moderate in the basins. General fertility level is medium with high CEC and K status.
13. *Ganges Tidal Floodplain*: Most topsoils are acidic and subsoils are neutral to mildly alkaline. General fertility level is high with medium to high organic matter and very high CEC. Limitations are due to high exchangeable Na and low Ca/Mg ratio.
14. *Gopalganj–Khulna Beels*: Potentially strongly acidic; organic matter content is medium to high. Low in P status. The fertility level is medium.
15. *Arial Beel*: Moderately acidic; organic matter content generally exceeds 2 %. High CEC and the general fertility level is medium to high.
16. *Middle Meghna River Floodplain*: Topsoils are strongly acidic and subsoils slightly acidic to slightly alkaline. General fertility level is medium with low N and organic matter.
17. *Lower Meghna River Floodplain*: Topsoils are moderately acidic and subsoils are neutral. The general fertility level is medium to high with low to medium organic matter.
18. *Young Meghna Estuarine Floodplain*: Mildly alkaline. General fertility is medium but low in N and organic matter. Sulphur status is moderate to high.
19. *Old Meghna Estuarine Floodplain*: Topsoils are moderately acidic, but subsoils are neutral. The general fertility level is medium. K status is low in uplands and low to moderate in lowlands.
20. *Eastern Surma–Kushiyara Floodplain*: Strongly acidic to neutral. Organic matter content is moderate. CEC and Zn level are high; other essential nutrients are medium.
21. *Sylhet Basin*: Mainly acidic; organic matter content is moderate. Fertility level is medium to high with low P and high Zn content.
22. *Northern and Eastern Piedmont Plain*: Slightly acidic to strongly acidic. General fertility level is low to medium.
23. *Chittagong Coastal Plain*: Moderately acidic. Organic matter content is low to moderate. The general fertility level of the soils is medium, but N and K are limiting. Status of S is high.
24. *St. Martin's Coral Island*: Neutral; general fertility level is low.
25. *Level Barind Tract*: Slightly acidic to acidic; organic matter status is very low. Most of the available nutrients are limiting.
26. *High Barind Tract*: Acidic to strongly acidic; low organic matter status. General fertility status is low. Zn level is medium to high.
27. *Northeastern Barind Tract*: Strongly acidic; low organic matter. General fertility level is poor with high Zn status.

28. *Madhupur Tract*: Strongly acidic with low organic matter status. Low fertility level. Soils are mainly phosphate fixing and low in K, S, and Ca.
29. *Northern and Eastern Hills*: Acidic; low organic matter. General fertility level is low.
30. *Akhaura Terrace*: Strongly acidic with low organic matter. General fertility is low.

10.1 Major Constraints of Bangladesh Soils: General Fertility and Health

Bangladesh soils as such are not fertile. Soil fertility levels need to be managed through judicious application of fertilizers to keep the crop yield sustainable. In Bangladesh, crops respond dramatically to fertilizer on most soils (Figs. 10.1, 10.2, 10.3) (BARC 2005).

In Bangladesh, in terms of agriculture, the lands are classed as

Very good agricultural land	1.56 %
Good agricultural land	34.31 %
Moderate agricultural land	39.39 %
Poor agricultural land	15.84 %
Very poor agricultural land	8.90 %

There is an absolute need to intensify agricultural production where fertilizers play a vital role.

Intensification of agriculture in Bangladesh has resulted in higher demand for fertilizer because of higher crop removal (nutrient mining) of all essential plant nutrients. The increased cultivation of high-yielding variety (HYV)

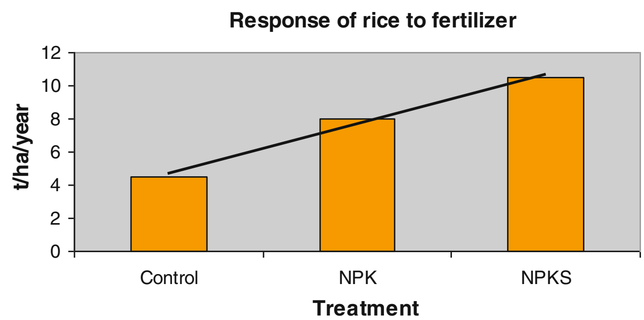

Fig. 10.1 Response of rice to fertilizer application

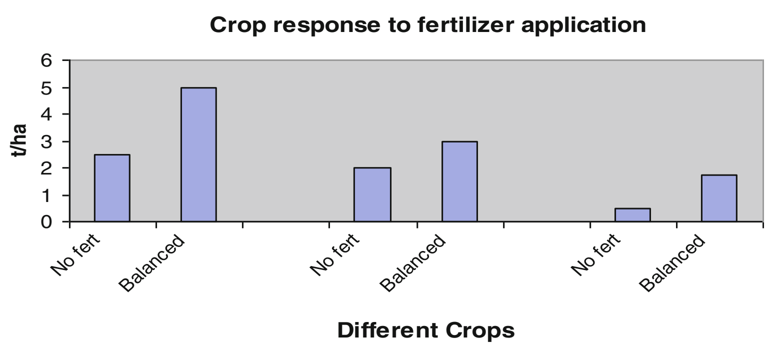

Fig. 10.2 Response of rice, wheat, and mustard to fertilizer application

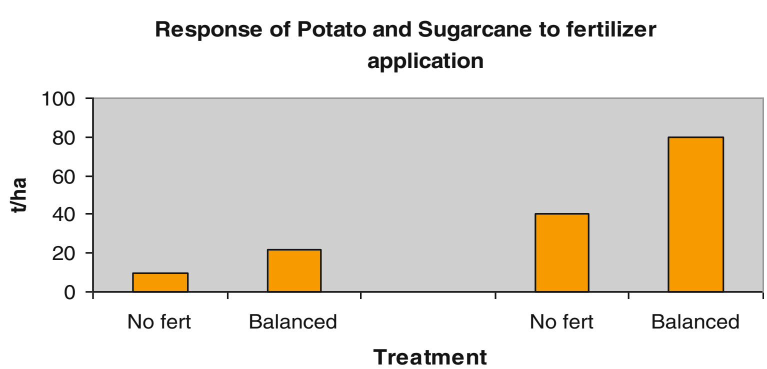

Fig. 10.3 Response of potato and sugarcane to fertilizer application

Table 10.1 Nutrient uptake (kg/ha) by important field crops with yield obtained at farm levels using recommended levels of fertilizers

Crop	Yield, t/ha	N	P	K	S
HYV Rice	5.80	102.8	17.0	138.9	10.5
HYV Wheat	3.20	89.2	16.8	74.1	12.8
Potato	30.90	109.0	20.0	132.0	13.0
Tobacco	2.25	6.3	8.0	72.0	11.0
Sugarcane	88.70	60.0	50.0	226.3	31.3

Table 10.2 Amount of different fertilizer use during 1999–2000 and 2006–2007

Source of fertilizer	1999–2000 (tons)	2006–2007 (tons)
Urea	2,151,100	2,515,000
TSP	259,300	340,000
SSP	237,200	122,000
DAP	109,200	115,000
MOP	239,500	230,000
Gypsum	189,400	72,000
Zinc	1,200	26,000
AS	26,000	6,700
NPKS	–	12,500
Total	**3,212,900**	**3,612,000**

crops and expanding irrigation facilities led to an approximate fourfold increase in the consumption of fertilizer in Bangladesh from 870,000 tons in 1980 to 3.44 million tons in 2009–2010. For current production of food crops, annually 1.25 million tons of nutrient (N, P, K, and S) are being mined. The annual depletion of nutrients (N,P,K, and S) is 180–250 kg/ha/yr (Table 10.1).

The depletion of soil fertility has arisen principally due to increasing cropping intensity, increasing use of MVs, soil erosion, sandy soils, and higher decomposition of organic matter due to the subtropical humid climate. The highest nutrient mining occurs with K, because the farmers are using lesser amounts of K fertilizer. An excellent opportunity exists to arrest K mining by retaining 50 % crop residues (e.g., rice straw) in the field. Nitrogen is the most deficient element in Bangladesh. More than 60 % loss of urea-N occurs in wetland rice culture. There is scope to reduce this N loss from soils. Efficient research is needed on the aspect of reducing the N loss from soils and increase N use efficiency, particularly in wetland rice systems. We should not worry about P, inasmuch as this element balance was found to be slightly negative to slightly positive across the soils and cropping systems. As time advances, new nutrient deficiencies arise, such as the micronutrient deficiency of Zn, B, and Cu, for example, which has arisen in some soils and crops.

As such, there has been a steady rise in the consumption of various fertilizers over the years. Table 10.2 gives a comparison of the use of various fertilizer from 1999–2000 to 2006–2007.

10.1.1 Soil Reaction

The average pH of Bangladesh soils is on the acidic side of the pH scale (Fig. 10.4). Most soils have pH between 5.5 and 6.5. The Gangetic alluvium soils, particularly the calcareous ones, have pH greater than 7.0, reaching at times up to 8.5. These are, however, not alkaline. Soil plateaus raised lands, and hills are usually acidic in nature. Because of pH variations, the nutrient availability, particularly that of P and some micronutrients, is affected. Otherwise, lowland rice cultivation is not affected by soil reaction, as the pH tends to come to a value of around 7.0 on submergence. Liming is needed in soils having pH less than 4.5, which is more prominent in tea soils and hill soils.

10.2 Organic Matter Status

The organic matter status of Bangladesh soils is one of the poorest in the world. The average OM content is less than 1 % ranging between 0.05 and 0.9 % in most cases. Soils of peat lands and some lowlying areas usually contain OM higher than 2 % on average. The OM supply in soil is one of the major constraints for the country's agriculture. Most Bangladesh soils show an improved response when OM is incorporated along with inorganic fertilizers. The recommended doses vary between 5 and 10 tons ha^{-1} of fresh or partially decomposed cow dung. Use of green manuring plants such as *Sesbenia rostrata* is also encouraged. Use of compost is absent or insignificant. However, farmers are

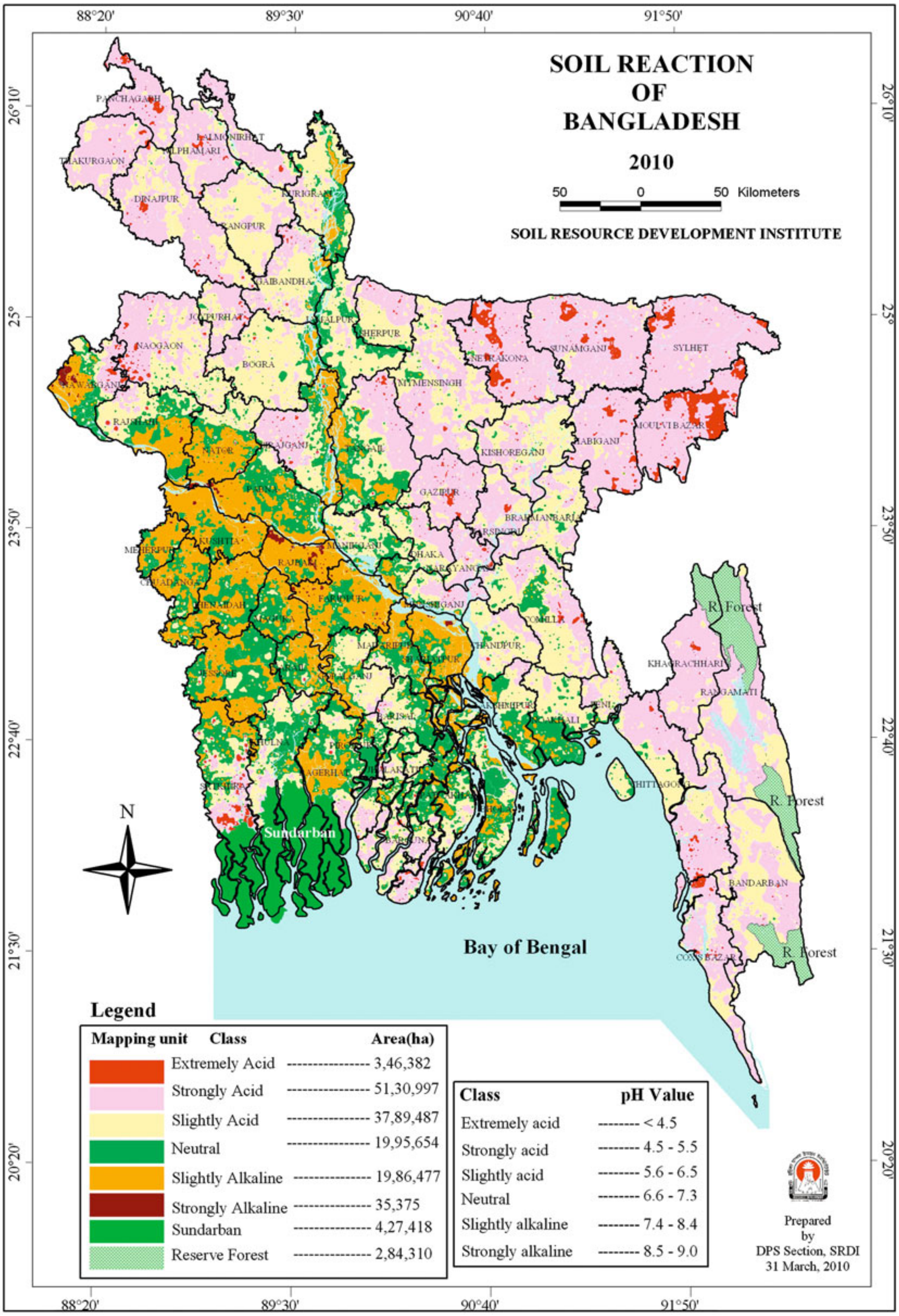

Fig. 10.4 The distribution of soil reaction in Bangladesh (*source* SRDI)

now being shown the benefit of the use of compost and organic fertilizers.

10.3 Nitrogen Status

Because of the low level of OM the nitrogen status of Bangladesh soils is quite low and most crops on all soils respond to applications of N. In fact, N fertilizers are the major fertilizers consumed in the country. The country has as many as six fertilizer factories producing mostly urea using natural gas. An increase of two- to threefold is common in most crops including rice with N fertilizers over no fertilizers. The N fertilizer consumption during 2010–2011 was more than 3 million metric tons (MoA 2012).

The critical limit set for total N (%) is 0.12. On the basis of the total N (%) the N status of soils is categorized as: very low: ≤0.09; low: 0.091–0.18; medium: 0.181–0.27; optimum: 0.271–0.36; high: 0.361–0.45; and very high: >0.45.*

10.4 Phosphorus Status

The available P in Bangladesh soils could be considered between low to medium. Most soils respond to P fertilization. P availability is pH dependent. The P supply source in soils is inorganic fertilizer. This again, is not proportionate to the supply of inorganic N. Many soils fix applied P. The recovery rate is 30 % on average by the first crop. The critical limit for P (μg/g soil) is 10.0 for neutral and calcareous soils and 7.0 for acid soils (Fig. 10.5).

10.5 Potassium Status

Bangladesh soils are not deficient in potassium although many soils are found to respond to K fertilization. These are particularly nonalluvial soils and the coastal saline soils. The critical limit for NH_4OAc extractable K in Bangladesh soils for rice is considered to be 0.12 meq %. Soils high in 2:1 expanding lattice clays (illites, chlorites, and montmorillonites) fix applied K. Although the coastal saline soils have K content higher than 0.12 meq %, it is the high Na content that makes them K responsive (Fig. 10.6).

10.6 Sulphur Status

Response to S application is common in most soils except in coastal saline soils, acid sulphate soils, and some acidic soils. Irrigated crops in the northern districts respond markedly to S application. About 4 million ha of land are supposed to be S-responsive. Gypsum is the principal source of sulphur. An application rate of up to 20 kg ha^{-1} is recommended in many places for most crops. The critical limit for S (μg/g soil) has been set at 10.0 (Fig. 10.7).

10.7 Zinc and Boron

During the recent past, soils, particularly those under constant water logging and irrigation, such as the calcareous flood plain soils have been found to respond to Zn and B applications. About 1.7 million ha of land have been estimated to be deficient in Zn supply. The recommended rates for Zn application are up to 5 kg ha^{-1} in the form of either ZnO or $ZnSO_4$ and that for B is 2 kg ha^{-1}. Critical limits for Zn (μg/g soil) and B (μg/g soil) have been set at 0.6 and 0.2, respectively (Figs. 10.8, 10.9).

10.8 Other Micronutrients

Response to micronutrients other than Zn and B has not yet been reported in any soil for any particular plant. However, it is doubtful that in some peatland soils and other soils, Mn application might lead to a positive response. It has not yet been confirmed. The critical limits for Fe, Cu, and Mo (μg/g soil) have been set at 4.0, 0.2, and 0.1, respectively.

10.9 Cation Exchange Capacity

The cation exchange capacity of soil is a determining factor in the status and maintenance of soil fertility. The greater the CEC of soil, the better is the fertility level. This property again is dependent on the organic matter status of soils and nature of clay minerals. In addition to organic matter content, the prevalence and abundance of 2:1 expanding lattice-type clay minerals are helpful in having higher CECs. Bangladesh soils are generally poor in organic matter. The clay minerals are mostly 1:1 type. As such, the CEC of Bangladesh soils is not appreciably high. Soils are classified on the basis of CEC (meq %) as very high >30; high 15–30; medium 7.5–15; low 3–7.5; and very low <3.

10.10 Soil Salinity

A vast portion of the coastal area is subjected to seasonal salinity. The salinity is mainly of $Cl–SO_4$ type. As it is caused by marine water intrusion, the Ca:Mg ratio in the coastal saline soils is less than 1.0, which creates severe fertility problems. Most lands in saline areas are under single crop. Application of K fertilizers up to 60 kg ha^{-1} has

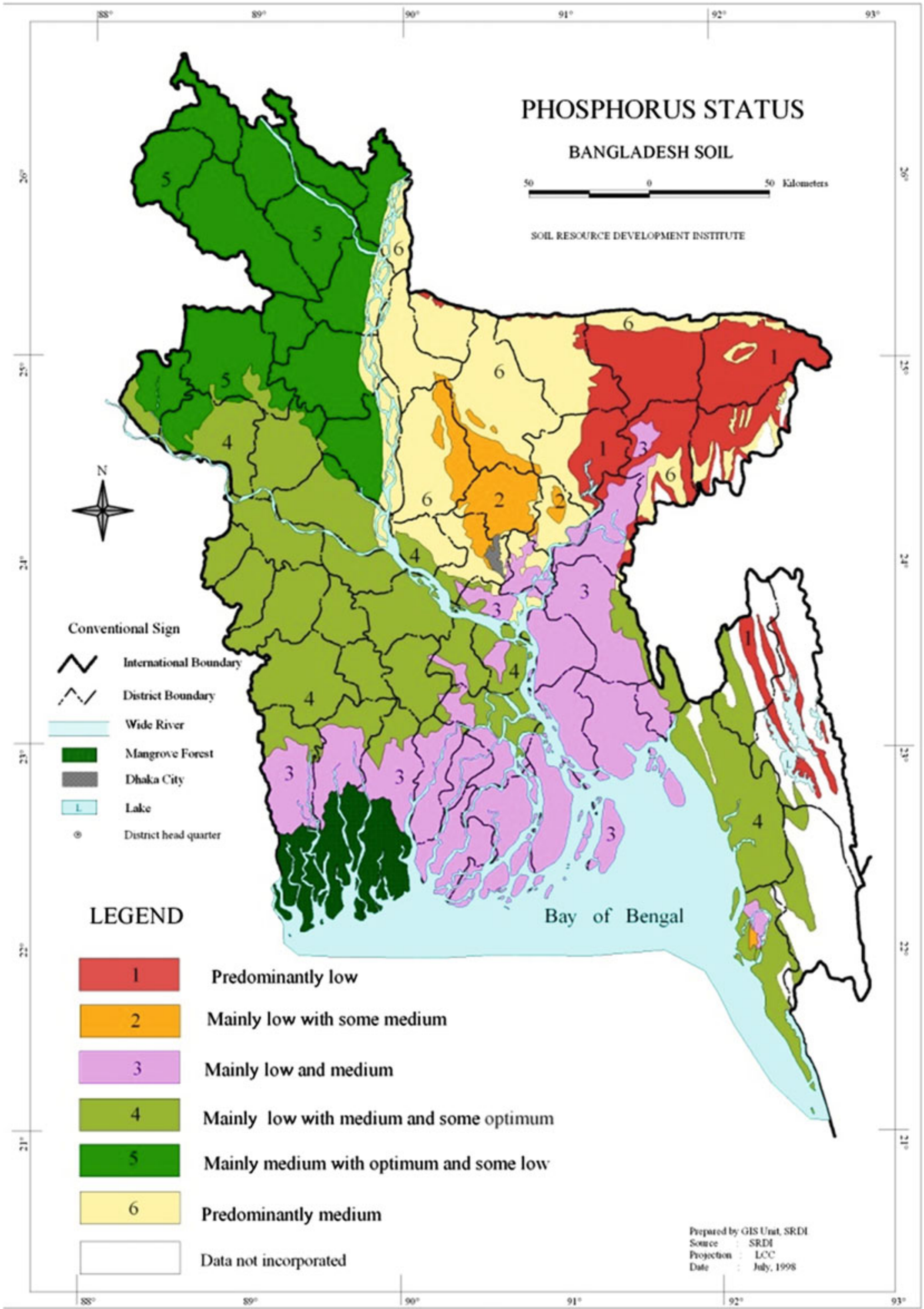

Fig. 10.5 Phosphorus status of Bangladesh soils (*source* SRDI)

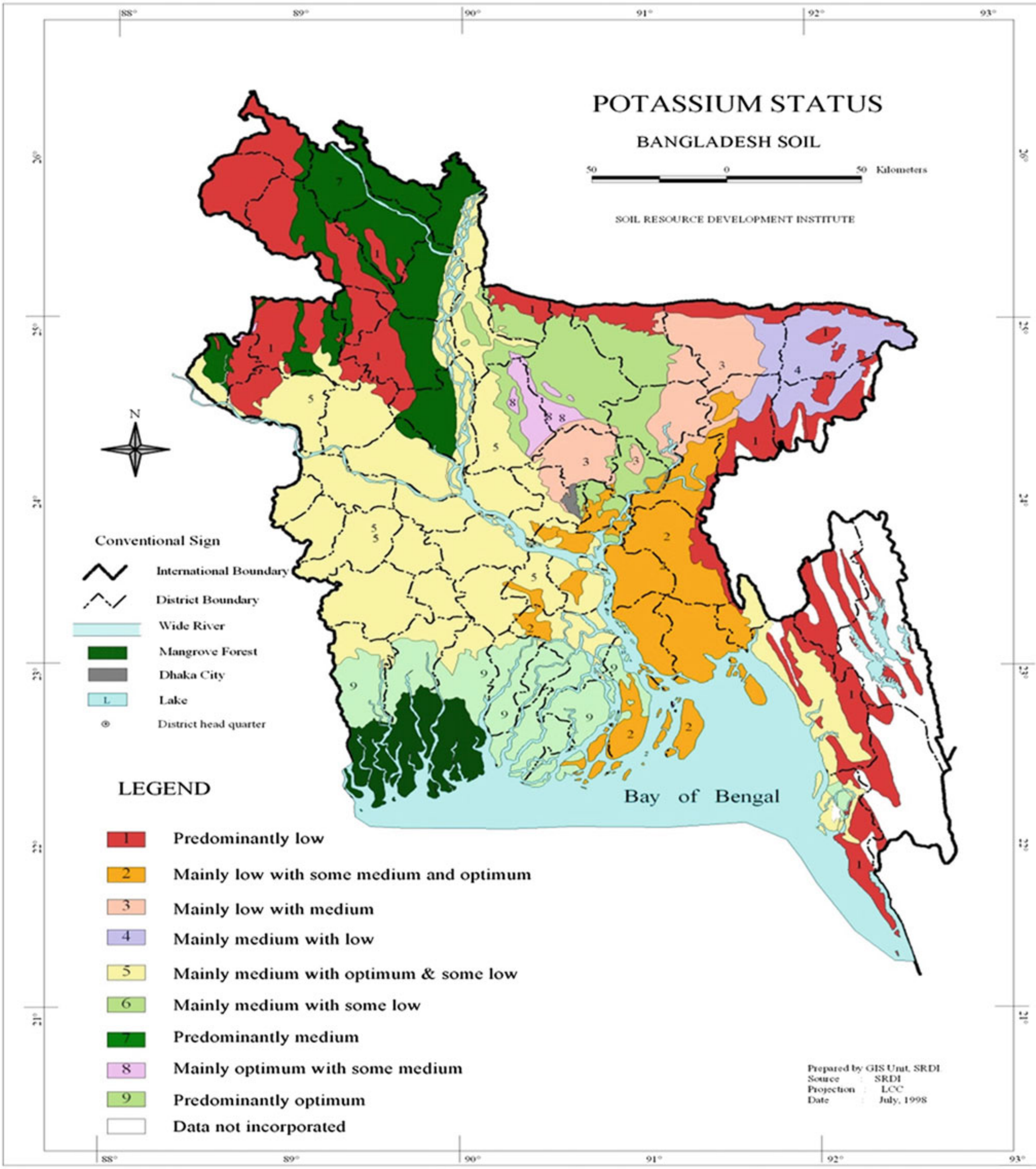

Fig. 10.6 Potassium status of Bangladesh soils (*source* SRDI)

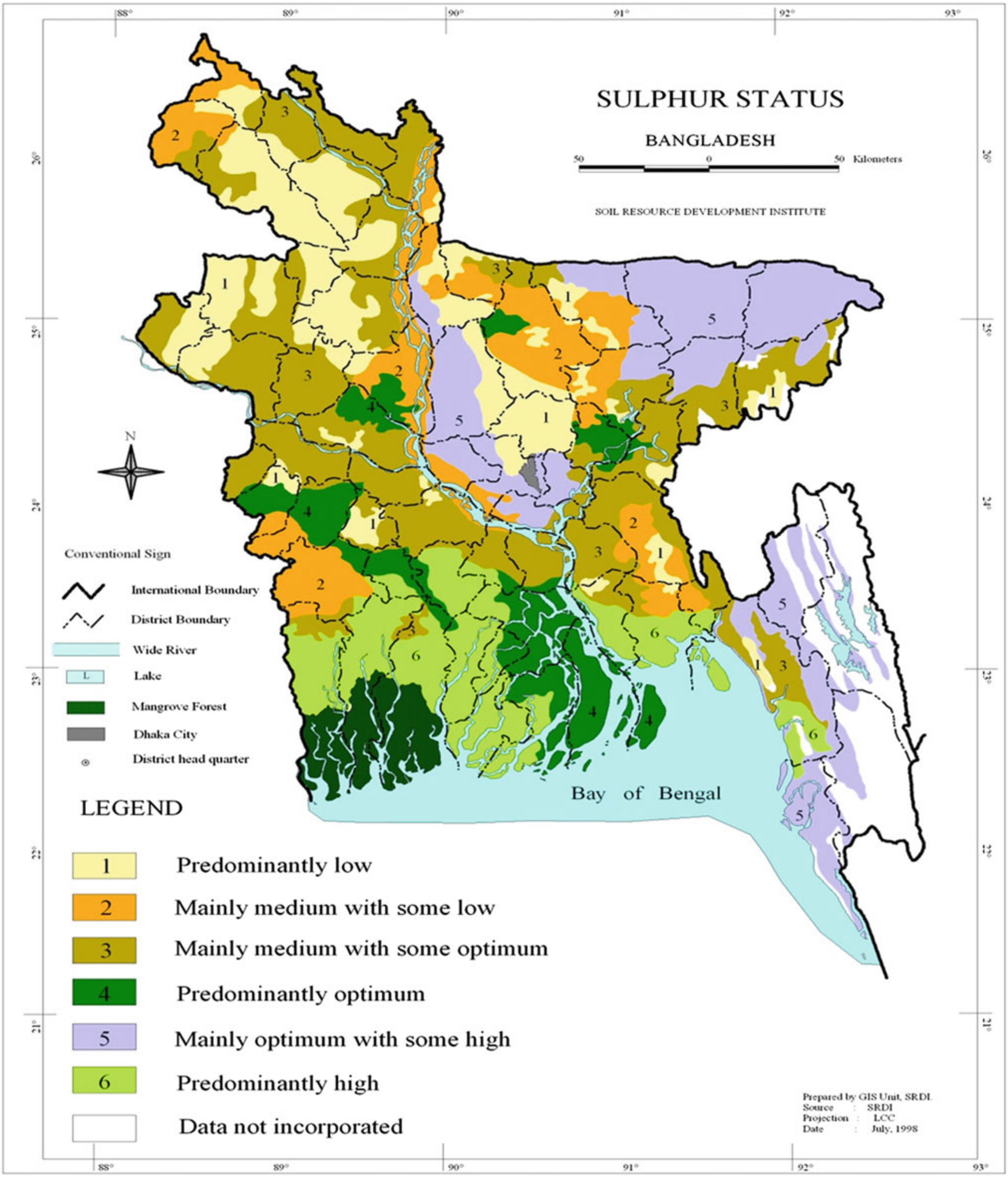

Fig. 10.7 Sulphur status of Bangladesh soils (*source* SRDI)

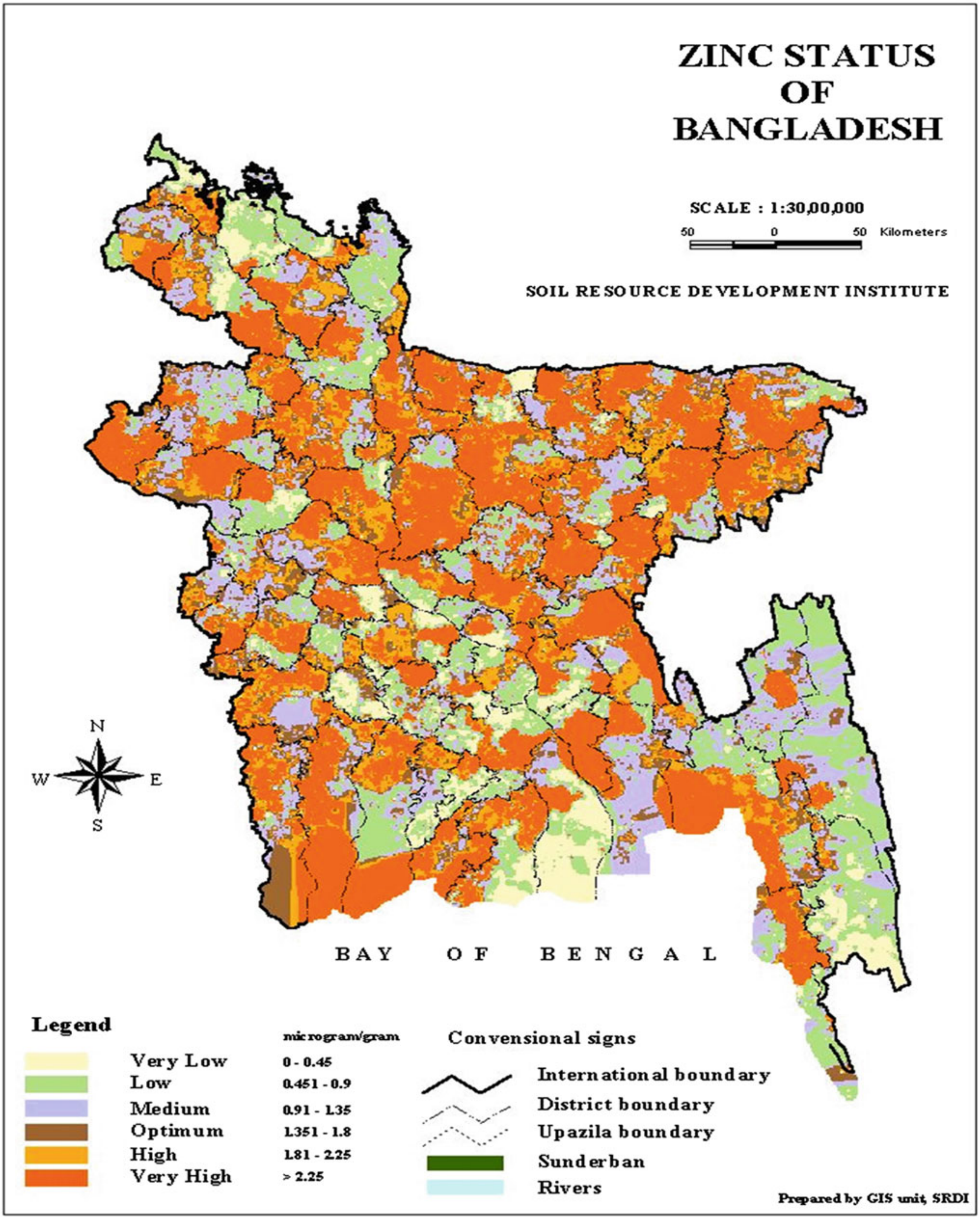

Fig. 10.8 Zinc status of Bangladesh soils (*source* SRDI)

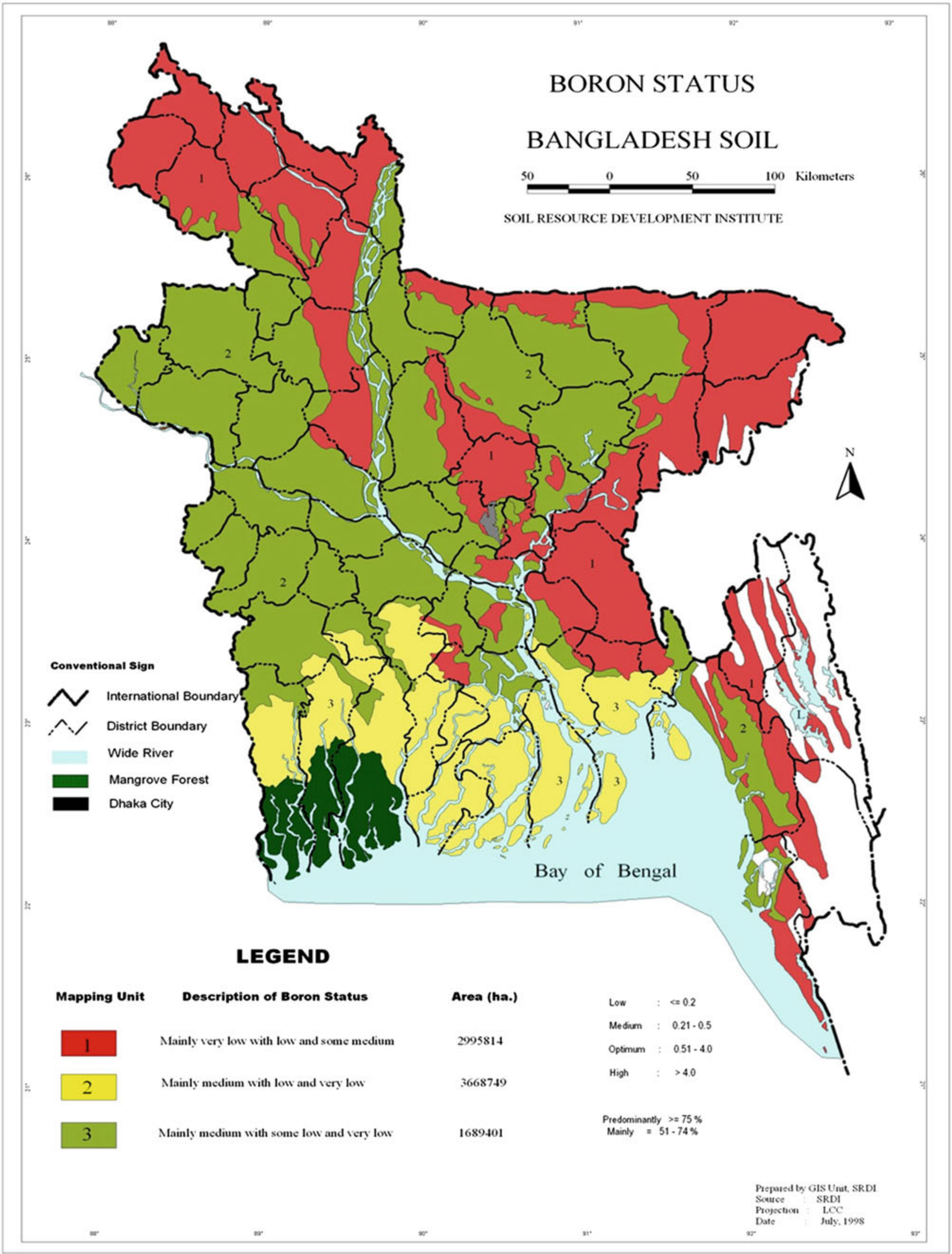

Fig. 10.9 Boron status of Bangladesh soils (*source* SRDI)

been found to increase crop yield substantially. Details about saline soils of Bangladesh were discussed earlier.

10.11 Problem Soils

The extent of problem soils in the country is substantial. These include soils with high acidity, highly saline soils, soils with high erodibility, and soils in the depressions. Soils with very low organic matter content are also considered problem soils. The details about problem soils are discussed in Chap. 7. These soils need special soil–water–fertilizer–crop management practices to make them productive.

10.12 Contaminants

At present arsenic is considered the single most important contaminant in Bangladesh soils. The source of As in the ground water is geogenic. The depth of As-laden groundwater is variable depending upon the depth of the layers containing oxidizable/reducible As-containing minerals. Soils irrigated with As-laden water are being contaminated with the element. Accumulation of As on the upper horizons is also likely to occur through the water's capillary rise during lean periods. The maximum values obtained for As in soils are in the range of 10–12 ppm. Soils are also being contaminated by Pb, Cd, Cr, and many organics. These mainly occur around the industrial belts and sewage disposal areas in the peri-urban areas. Motor vehicle exhausts also contribute to substantial lead accumulation in agricultural lands. Disproportionate use of nitrogenous fertilizers sometimes leads to NO_3 pollution in the ground- and surfacewater. The accumulation of pesticide residue is another source of contamination, which, although not marked, cannot be ignored, and needs to be properly and addressed in a timely manner.

10.13 Misuse and Abuse of Soils

Many agricultural lands are devolving to urbanization or industrialization. It has been estimated that 1 % of our arable land is disappearing each year due to these activities. One can find numbers of brick kilns set up on fertile agricultural lands along the highways. As these lands are privately owned, the government has practically no control on their appropriate use. Forestlands are also becoming urbanized and industrialized. Only about 7 % of the total land area is under forest cover now. Overexploitation, that is, using the soil for intensive cultivation without replenishing it, is causing nutrient mining to an extent that ultimately will make it barren. Greed mingled with lack of farsightedness, proper awareness, and absence of punishable laws has aggravated the misuse and abuse of the limited land that is taking a heavy toll on our soils.

One needs to ponder the quality of soil for future generations. Soil health needs to be improved and for that reason organic matter incorporation has to be accentuated, coupled with rational use of agrochemicals. The misuse and abuse of our land resources needs to be minimized at the same time. Remediation measures for major soil contaminants need to be undertaken (Imamul Huq 2003).

Research is needed to determine all the deficient elements and management is needed on a sustainable basis. Fertility management systems that are profitable for short-term and sustainable for long-term should be formulated and they need to be confirmed by on-farm research trials. We need to explore and utilize as much as possible the biologically fixed N, both symbiotic and nonsymbiotic (Jahiruddin and Sattar 2007).

Land and soil resource management research should give special attention to ecologically disadvantaged areas such as coasts, hills, and char lands where research is still insufficient. Soil erosion is a major constraint in hilly areas. Sloppy lands and light-textured soils, coupled with shifting cultivation are responsible for soil erosion. So, conservation agriculture techniques, for example, cover crops, contour, and strip cropping should be investigated.

Soil fertility research is meager on horticulture crops, especially fruits and vegetables, although nutrient management is important for improvement of mineral nutrition, apart from yield advantage.

The country is prone to natural hazards such as drought, flood, and the like, and experiencing climate change, including a rise in temperature and change in rainfall pattern. Its impact on natural resources, especially land, soil, and water needs to be investigated.

There are some policy issues concerning fertilizer management practices. The quality of nonurea fertilizers is often below standard. It has been found that there is more than 80 % adulteration in mixed fertilizers (NPKS), more than 50 % adulteration in privately imported SSP and TSP, and 25–30 % adulteration in MoP and DAP. Strong monitoring is needed at the storage and distribution points to check adulteration of these fertilizers. Farmers are using smaller amounts of TSP and MoP creating an unbalanced use of fertilizers, which produces a negative impact on soil fertility and crop yield. Farmers should be motivated to the balanced use of fertilizers, with an integrated nutrient management approach. Farmers are also using a minimum amount of organic fertilizers. Furthermore, they are using a significant portion of cow dung as fuel. Policy support is needed to increase the use of organic fertilizers. Further policy support

is needed to increase the ability of marginal and small farmers to buy nonurea fertilizers (MoA 2012).

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11 Land Use and Vegetation

With the growing population, and their increasing needs in various sectors, the land use patterns of Bangladesh are undergoing a qualitative change in which the areas under the net cropped land and forestland is gradually shrinking. Because of a hyperthermic temperature regime, agricultural production in the country is possible throughout the year. More than 60 % of the land area of Bangladesh is used for agricultural purposes (Brammer 1997).

Land use in Bangladesh has evolved through natural forces as well as human needs. Cultivated land, forestland, settlements, and homesteads are the major land use types in Bangladesh. Table 11.1 shows the land use scenario of the country. As stated earlier, with the growing population and its increasing needs in various sectors, land use patterns are undergoing a qualitative change in which the areas under the net cropped land and forestland are gradually shrinking. A large part of the forestland is now under different types of nonforestland use including shifting agriculture, unauthorized occupation for homesteads, shrimp culture, and so on. Another important feature in land use in Bangladesh at present is the small area (only 3 %) of fallow land, which indicates that land in this country is not allowed a sufficiently long rest period for regaining its natural biophysical properties which are vitally needed for good maintenance of soil health. It is perhaps needless to say that for sustained agricultural production maintenance of good biophysical condition of soil is essential.

The land area under the heading “Not available for cultivation” includes mainly urban, rural settlements and industrial lands and covers approximately one-fourth of the total national land area. The area covered by homesteads is around 9.3 % of the total land area and is characterized by intensively planted but not efficiently managed agroforests. Areas under double and triple cropping show an increasing trend over time. Cropping intensity, which may be an indicator of land use intensity, is gradually increasing to 181 % in 2010 from 176 % in 1996–1997 (MoA 2012). It has been stated earlier that moderately good and good agricultural lands together constitute the bulk of the land area in Bangladesh. Because there is an acute shortage of land in the country, naturally there is always competition among the various land uses. Agriculture, being the dominant land use type, is in constant conflict with other uses. Land type, area, and proportion of the country’s total area are shown in Table 11.2 and in Fig. 11.1.

There is also competition for land within each use type. The shortage of land is so serious that more than 50 % of farmers in the country are considered to have become landless and many people are compelled to settle in the undeveloped offshore islands when these appear in the middle of riverbeds or in the offshore areas, risking their lives. Some of these undeveloped and unstabilized charlands are inundated during high tide and dry out during low tide. The conflict between agriculture and urbanization is the direct result of population increase, as new housing is needed for new families. Agricultural lands owned by parents are being converted to homesteads for building new houses to accommodate their offspring. The net result is the decrease of total agricultural land and an increase in the number of smaller-sized plots. As growth is going on in all sectors of the economy, more and more lands are being diverted to development activities for building townships, industries, educational institutions, roads and highways, and the like. The decimation of forests for agricultural use and human settlement near the fringe of forests is very common and in this process the actual forestland under tree cover is estimated to have gone down to 6 % at present. The competition for land between agriculture and livestock has become very acute. At present there are about 37 million bovine populations for which there is no demarcated grassland. This huge bovine population thrives mainly on rice straw and grasses that grow on road- and canalside patches and homestead areas. Seasonally the cattle can graze in the agricultural fields during their short fallow period. But these fields are rarely available for grazing as these are used for double or triple cropping.

Shrimp culture is mainly concentrated in the coastal areas of Bangladesh where the previous croplands and

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Table 11.1 Land use scenarios in Bangladesh

Land use types	Hectares (in 000)	%
Total land area	14,845	100
Not available for cultivation	3,700	24.9
Forest	2,255	15.2
Cultivable waste	445	3.0
Current fallow	2,999	20.2
Double-cropped area	979	6.6
Single-cropped area	451	3.0
Triple-cropped area	4,013	27.0
Net cropped area	7,992	53.8
Total cropped area	13,964	–
Net cultivable area	9,443	56.9

Source BBS (1999)

forests have been converted to shrimp culture fields. When these fields are abandoned they cannot easily be converted to croplands, as these fields become saline due to use of brackish water for shrimp culture. The estimated area of shrimp cultivation in four coastal districts of Khulna, Satkhira, Bagerhat, and Cox's Bazar is 140,000 ha, around 70 % of which are located in the greater Khulna district. Although economically profitable, the unplanned expansion of shrimp culture has created a negative impact on water quality, mangrove deforestation, and degradation of agricultural land. Chakoria Sundarban along the southeastern Chittagong coast has almost disappeared due to the encroachment by shrimp farms (Bashar 2001).

Good quality agricultural lands are randomly being used as brickfields all over the country but their concentration is more in the villages and in peri-urban localities. About 4,000 brickfields require soils and woods as fuel, which indiscriminately destroy trees, homesteads, forests, and agricultural lands. When the brickfields are abandoned they cannot be easily converted to crop fields as burnt soils cover the land there. So the loss of land due to brickmaking becomes more or less permanent.

Table 11.2 Land type, area, and proportion of country's total area

Land type	Area (ha)	Proportion (%)
Highland	4,199,952	29
Medium highland 1 and 2	5,039,724	35
Medium lowland	1,771,102	12
Lowland	1,101,560	8
Very lowland	193,243	1
Total soil area	**12,305,581**	**85**
River, urban, homesteads, etc.	2,178,045	15
Grand total	**14,483,626**	**100**

Source FAO-UNDP (1988a)

The agricultural land use pattern is ever changing. The map in (Fig. 11.2) shows the scenario of agricultural land use in the country. The land use pattern is a dynamic process in this country to cope with the adequate agricultural exploitation of the climatic potential or sustained maintenance of productivity that largely depends on soil fertility and using soil on an ecologically sound basis. The following basic soil requirements for crop plants have played a role in the development of the agricultural land use pattern of the country.

(i) The soil temperature regime as a function of the heat balance of soils, which, in turn, is related to annual, seasonal, and/or daily temperature fluctuation
(ii) The soil moisture regime, as a function of the water balance of soil as related to the soil's capacity to store, retain, transport, and release moisture for crop growth, and/or to the soils permeability and drainage characteristics
(iii) The soil aeration regime, as a function of the soil–air balance as related to its capacity to supply and transport oxygen to the root zone and remove carbon dioxide
(iv) The natural soil fertility regime, as related to the soil's capacity to store, retain, and release plant nutrients in such kinds and properties as are required by crops during growth
(v) The effective soil depth available for root development and physical support of the crop
(vi) Soil texture and stoniness, at the surface and within the whole depth of soil, required for normal crop development
(vii) The absence of soil salinity and of specific toxic substances or ions deleterious to crop growth
(viii) Soil accessibility and trafficability under certain management systems
(ix) Other specific properties, for example, soil tilth as required for germination and early growth.

11.1 Land Suitability Classification

In order to assess the suitability of soils for crop production, the properties of the soil must be known. The land suitability assessment brings together all the physical constraints and limitations likely to affect crop performance. The assessment takes account of all the inventories of the land (climate, inundation, soil, and landform) relevant to the crop being assessed and compares them to the crop's requirements so as to give an easily understood account of the suitability of the land for production of the particular crop.

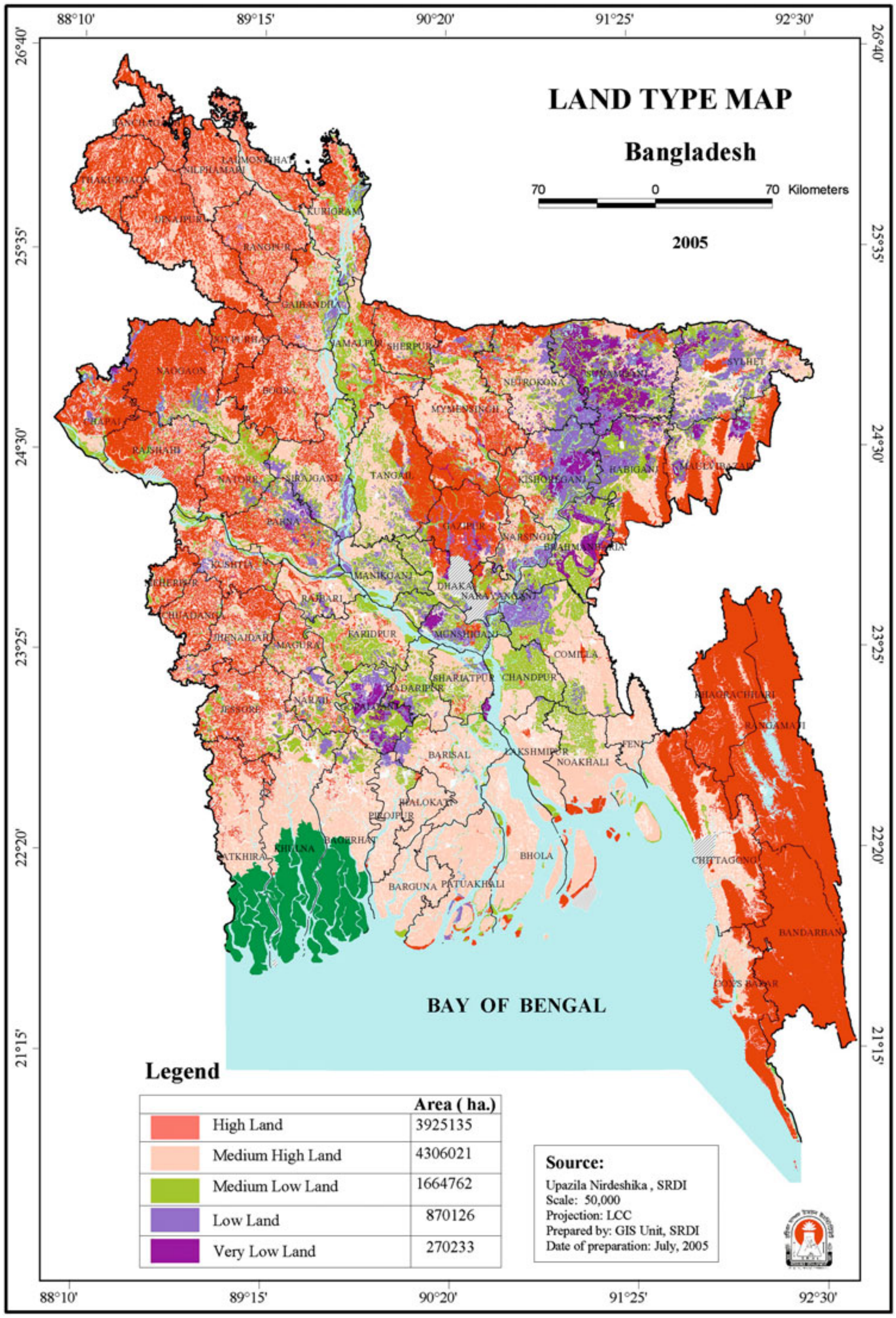


Fig. 11.1 Land type map of Bangladesh (*source* SRDI)

Accordingly, the lands of Bangladesh have been classified into five suitability classes. These are:

1. Very suitable (VS): 80 % or more of maximum attainable yield (MAY)
2. Suitable (S): 60–80 % of MAY
3. Moderately suitable (MS): 40–60 % of MAY
4. Marginally suitable (mS): 20–40 % of MAY
5. Not suitable (NS): less than 20 % of MAY.

The land capability classification of Bangladesh is similar to the land capability classification developed by the US Soil Conservation Service. On this basis Bangladesh soils, as per crop production, are categorized in (Table 11.3).

Although rice and jute are the primary crops, maize and vegetables are assuming greater importance. Due to the expansion of irrigation networks, some wheat producers have switched to the cultivation of maize which is used

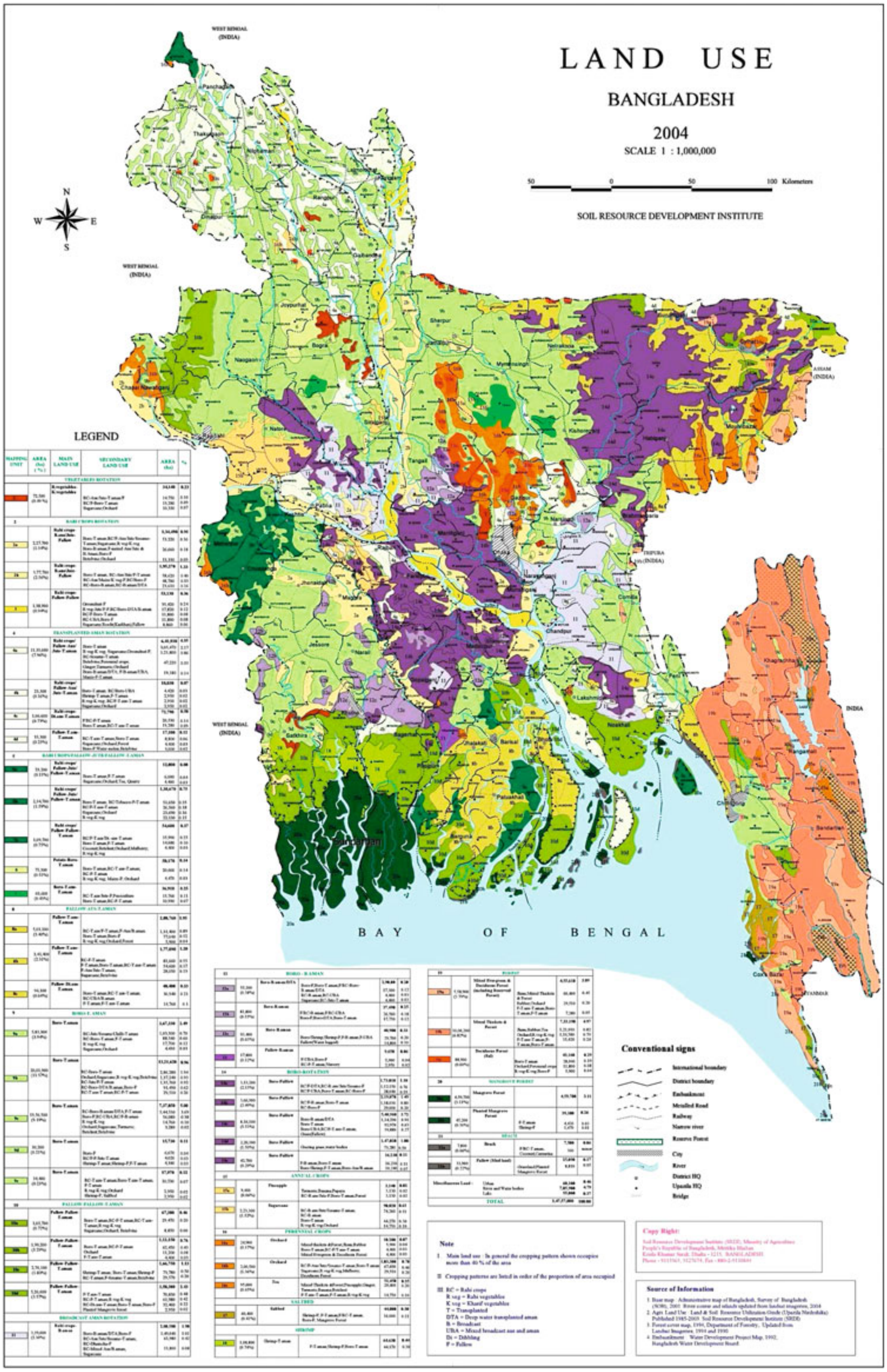


Fig. 11.2 Land use pattern of Bangladesh

Table 11.3 Land capability classes with their area

Land capability class	Area (million ha)	%
I. Very good	0.19	2
II. Good	4.19	34
III. Moderate	4.82	39
IV. Poor	1.92	16

Source FAO-UNDP (1988b)

mostly as poultry feed. Tea is grown in the northeast. Because of climatic favorability (temperature, sunlight) and type of culture (lowland culture), rice can be grown and harvested three times a year in many areas.

11.2 Cropping Pattern and Crop Seasons of Bangladesh

The cropping pattern of Bangladesh is mainly rice-based. Rice dominates the major cropping pattern throughout Bangladesh. There are three classes of rice—*aman* (transplanted and broadcast varieties), *boro*, and *aus*—which are classified as per their time of cultivation season. Starting in July, aman is harvested in December to January, boro starts in November to December and is harvested in March to May, and aus season starts in February to March and is harvested in July to August. The duration of aman is 150 d, boro 170 d, and aus 130 d. Among these three varieties, transplanted aman is the most important. Transplanted aman is grown almost everywhere in Bangladesh and covers about 46.30 % of the paddy area, followed by boro (26.85 %), aus (17.59 %), and broadcast aman (9.26 %). Broadcast aman is mostly grown in the lowlying areas of the south and northeast. Boro is grown in irrigated areas to a certain extent in every district, and aus is a well-scattered crop. The crop calendar is shown in Fig. 11.3.

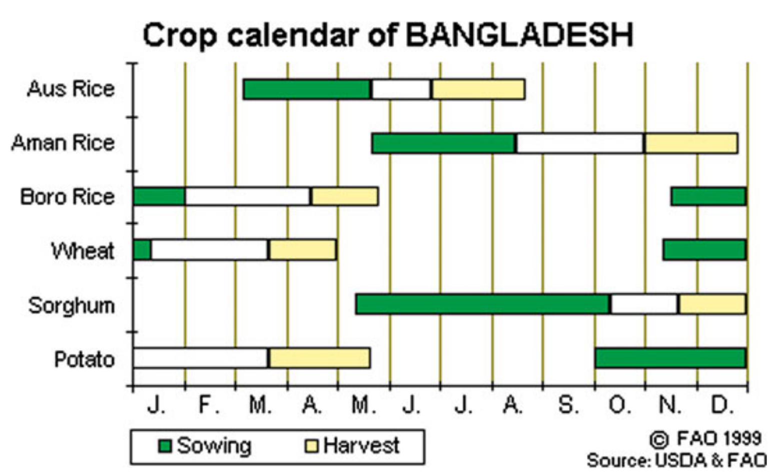
Due to the favorable climatic condition of Bangladesh several crops are grown on the same land each year. Most areas allow three crops a year with the exception of the Sylhet hoar basin, the drought-prone areas in the west, and the coastal areas. Rice is grown throughout the country with the exception of the Chittagong Hill Tracts. Wheat is predominantly grown in the northwest and in districts along the Padma River. The main vegetable-producing areas are in the west around the town of Jessore. Areas under major crops are shown in (Fig. 11.4).

The major cereal-cropping system of Bangladesh is rice and wheat grown on the same field but in different seasons during the year. Although the rice–wheat cropping pattern is the major cereal production pattern, farmers sow continuous cereals year after year. Although the area of rice–wheat may not change within years on a national level, farmers themselves are changing their cropping pattern within their plots. Farmers sow pulses, oilseeds, potatoes, vegetables, and sugarcane on the plots previously in rice–wheat. Commonly used two-crop combinations are aman–boro rice, aman–aus rice, and aman–boro rice; three-crop combinations are aman–boro–aus, aman–boro–jute, and aman–boro–pulse. Four-crop combinations are boro–aman–jute–mustard, boro–aman–mustard–aus, aman–aus–boro–tea, aman–boro–jute–wheat, aman–wheat–boro–aus, aman–boro–wheat–aus, and aman–aus–pulses–boro. Cropping patterns in different agroecological zones are shown in appendix table j. The table also shows the changing cropping pattern. Note that most of the lands that were kept fallow or barren have been brought under cultivation. The crop sequence is boro– Kharif I–Kharif II.

Because of its geographical location, Bangladesh is blessed with a favorable climate, and thus is able to plant several crops on the same land each year. The crop-growing period in Bangladesh is divided into two main seasons: Kharif and Rabi. The Kharif is again subdivided into Pre-Kharif or Kharif I and Kharif or Kharif II.

The major characteristics of the cropping seasons of Bangladesh are described in the following.

Fig. 11.3 Crop calendar of Bangladesh



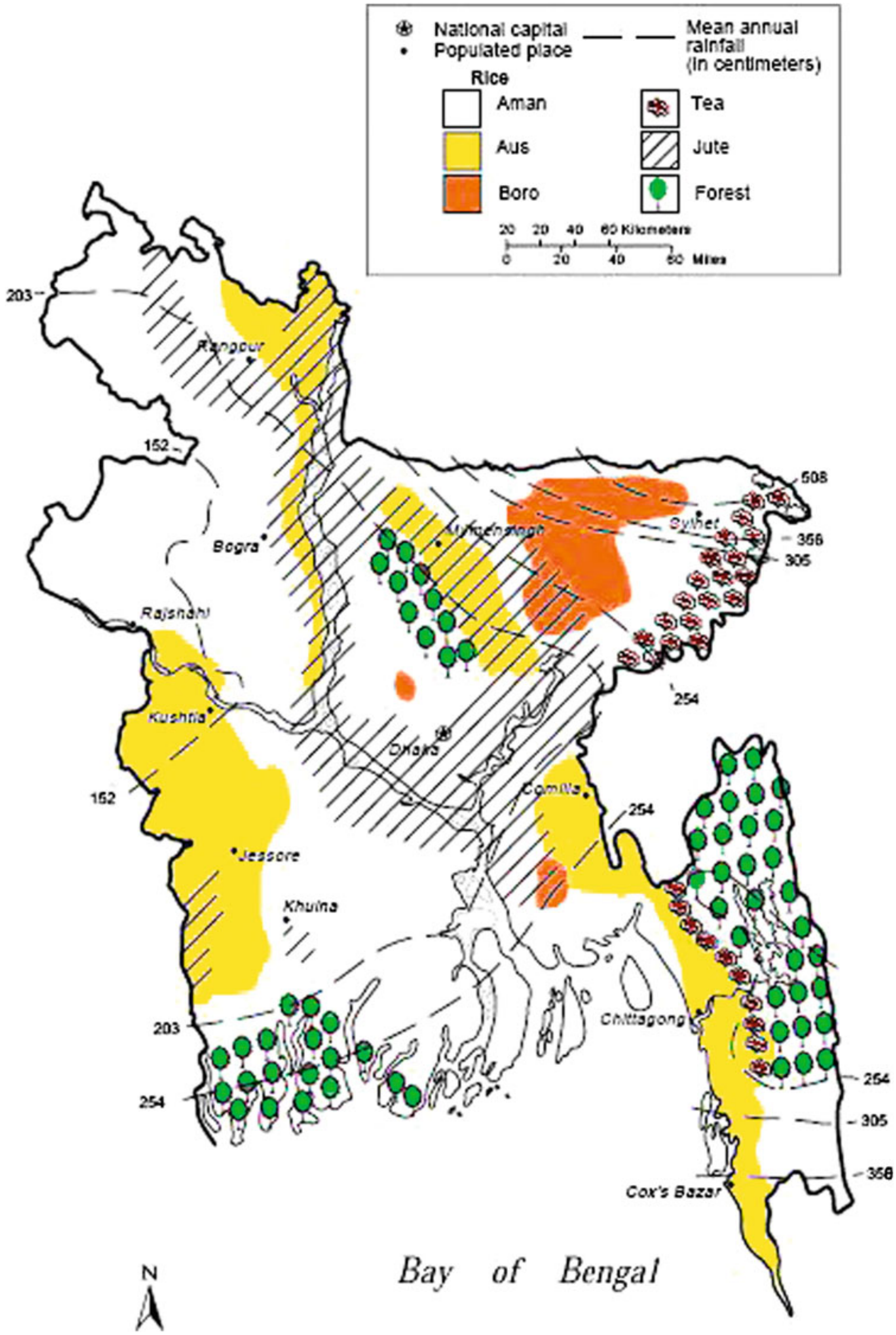


Fig. 11.4 Map showing the growing areas of major agricultural products (*source* http://en.wikipedia.org/wiki/Agriculture_in_Bangladesh)

11.3 Pre-Kharif (Kharif I) Season

This is characterized by unreliable rainfall and varies in timing, frequency, and intensity from year to year, and provides only an intermittent supply of moisture for such crops as jute, broadcast aman, aus, groundnut, amaranths, and teasel gourd, among others. During this transition period, soils intermittently become moist and dry. The relative lengths and frequency of such periods depend on the timing and intensity of premonsoon rainfall during this season in individual years. Kharif I starts from the last week of March and ends in May. With the expansion of irrigation facilities, some of the pre-Kharif crops are now grown under irrigated conditions. These include sugarcane, maize, jute, amaranth, groundnut, banana, sesame, lady's finger, teasel

gourd, sweet gourd, white gourd, bitter gourd, balsam apple, ribbed gourd, Indian spinach, ginger, turmeric, and so on.

11.4 Kharif (Kharif II) Season

This starts in May when the moisture supply from rainfall plus soil storage is enough to support rainfed or unirrigated Kharif crops. In general, the Kharif season starts in April and extends to November. The season actually begins on the date from which precipitation continuously exceeds 0.5 potential evapotranspiration (PET) and ends on the date when the combination of precipitation plus an assumed 100 mm of soil moisture storage after the rainy season falls below 0.5 PET. During the greater part of this season, precipitation exceeds full PET and water can be held on the surface of impermeable soils by bunds. The period of excess precipitation is called the humid period. The crops most extensively cultivated during the Kharif season are jute, aus, broadcast aman, transplant aman, sesame, different kinds of summer vegetables, ginger, turmeric, pepper, green chili, different kinds of aroids, cotton, mungbean, and black gram among others. Most Kharif crops are subject to drought and flood in areas without water control. Kharif crops are grown in the spring or summer season and harvested in late summer or in the early winter. The Kharif season is characterized by high temperature, rainfall, and humidity

11.5 Rabi Season

This starts at the end of the humid period and lasts to the pre-Kharif season, the Rabi season starts in November and continues up to April. The mean length of the Rabi growing period ranges from 100–120 days in the extreme west to 140–150 days in the northeast of the country. The mean starting date of the Rabi season ranges from October 1–10 in the extreme west, to November 1–10 in the northeast and in central and eastern coastal areas. The mean end dates range from February 1–10 in the following year in the extreme west to March 20–31 in the northeast. Most common Rabi or winter crops are wheat, maize, mustard, groundnut, sesame, tobacco, potato, sweet potato, sugarcane, lentil, chickpea, grass pea, and so on. On lowlands, very lowlands, and bottomlands where flooding continues even after the end of rainy season, the Rabi season starts from the date when flooding ends.

11.6 Crop Suitability in Relation to Flooding

The suitability of crops depends on the land type that again correlates with the flooding or inundation depth.

The limits among the depths of flooding classes are not rigid. Flood levels in an area may vary by as much as a meter or more between different years. They may also reach their peak levels for only a few days at a time during a particular year. These classes actually indicate the level of flooding that farmers expect when they decide which crops to grow in the Kharif season on different kinds of land, based on their long experience of cultivation on particular sites.

Highland may be suitable for Kharif or perennial dryland crops if the soils are permeable. Impermeable soils or soils that can be made impermeable by puddling may be suitable for transplanted aus and/or aman paddy if bunds are made to retain rainwater on fields. Medium highland is suitable for crops that can tolerate shallow flooding, such as broadcast or transplanted aus paddy, jute, and transplanted aman paddy. Early Kharif dryland crops that mature before the start of flooding can be grown on permeable soils, and late Kharif and early Rabi dryland crops on soils that drain in September–October. Medium lowland is flooded too deeply for transplanted aus or transplanted aman paddy to be grown reliably. Mixed broadcast aus and deepwater aman is a common practice; or long aman seedlings may be transplanted as the floodwater recedes. Dryland Rabi crops are widely grown on soils that drain in October or November. Lowland is flooded too deeply for broadcast aus or transplanted aman to be grown. Deepwater aman is typically grown on such land, although the cultivation of irrigated boro paddy on such land in the dry season now precludes the cultivation of deepwater aman over considerable areas of lowland. Dryland Rabi crops can only be grown if floodwater recedes before December. Very low land generally is too deeply flooded for even deepwater aman to be grown. Bottomland stays too wet for paddy to be sown broadcast. The traditional crop on such land is local boro paddy, either not irrigated or irrigated by traditional low-lift irrigation devices. In a few other areas where flooding normally does not exceed 1.5 m, very long aman paddy seedlings are transplanted early in the monsoon season. It needs to be emphasized here that land management (cropping seasons and cropping patterns) in this country is dependent on annual flooding. Sustainability in land management in Bangladesh faces a big challenge from the unusual flooding.

In addition to flooding, other conditions of drought, salinity, chemical pollution, and recently, arsenic pollution have a bearing on the land use and cropping pattern of Bangladesh. Drought is due to rainfall shortage and is usually mitigated in some areas by provision of irrigation, use of improved cultivation techniques, and the introduction of more drought-tolerant crop varieties such as millet, sorghum, ground nut, and legumes among others. In Bangladesh, drought is more severe in the southwestern part of the

country during the months of October to March. Against all odds, agricultural land use has improved over the recent past and as a consequence the cropping intensity of the country stands at more than 180. With limited land resources and increasing demands for urbanization and industrialization, the land use pattern of the country is likely to see further changes.

11.7 Land Use in the Coastal Area

The land use pattern in the coastal saline areas is dependent on the land types, that is, flooding depths and intensity of salinity. Depending on these two factors, mono, double, or triple cropping is practiced. In low salinity areas and on medium high to high lands, Kharif-1, Kharif-2, and Rabi crops are grown. The Kharif-1 and Kharif-2 crops are local varieties of aus and aman paddy. Among the Rabi crops, sweet potato is cultivated most, followed by pulses, chili, mustard, potato, and winter vegetables. The yield of all the crops, in the absence of improved fertilizer, soil, and crop management is lower than the national averages. In medium lowlands with low to moderate salinity, double cropping is practiced whereas in lowlands with moderate salinity only Kharif-1 (local aus) is grown (Imamul Huq and Iqbal 1995).

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12 Soil Management and Vulnerability

About 14 million hectares of the total area of Bangladesh are land surface. The arable land is about 8 mha that constitutes more than 61 % of the total land surface (Hussain et al. 2003). Of this land surface, 11.78 mha is under cereal production among which rice occupies 10.9 mha. It has been mentioned earlier that about 1 % of the arable land is being transformed by urbanization and the industrialization sector every year. Moreover, very good to good agricultural lands account for less than 50 % of the total arable land. A reconnaissance study by FAO-UNDP in 1981 on changes of land use of the country revealed a high rate of loss of farmland to human settlements, the building of roads, and the like in an unplanned manner. Recent observations reveal that in the peri-urban and not so remote rural areas, productive agricultural lands are being used for industrial/urban settlements and for brick manufacturing.

Bangladesh is one of the world's most densely populated countries and has limited scope for area expansion as most of the arable land has already been brought under cultivation. Urbanization and industrialization put pressures on agricultural land. Future growth will depend on raising the yield on major food grains, as average yield rates in Bangladesh are low in comparison with other countries in the region. Enhanced use of other agricultural inputs, mainly high-yielding seed varieties, fertilizer, and irrigation, will have a crucial role in increasing cropping intensity and yield. One of the key elements in this endeavor will be a good soil management approach. Appropriate land use and adoption of suitable soil management technology can enhance and sustain high productivity.

Soil nutrient management in Bangladesh for almost all crops grown has been on trial since the soils of this country were classified, taking into consideration their basic physicochemical properties. The fertilizer recommendation guide published by the Bangladesh Agricultural Research Council is updated routinely every 5–6 years and each new edition incorporates the major anthropogenic changes in soil usage. The growing demand of the ever-increasing population of Bangladesh for growing more food, fuel, and timber has resulted in overexploitation of its soils, massive deforestation, and ecological imbalance. Land use changes in Bangladesh and activities related to land degradation are affecting the socioeconomic condition and the agricultural system of the country. The important impact of agriculture in Bangladesh is the gradual degradation of its land resources. Land degradation is taking place due to both natural as well as anthropogenic causes. Natural hazards such as sudden flash floods, tidal surges, and drought situations cause agricultural vulnerability. Significant land degradation processes due to soil erosion, soil salinization, continuous water logging, riverbank erosion, shifting cultivation, acidification, plowpan formation, organic matter reduction, and deforestation, among others are having a heavy impact on proper land use planning and appropriate land management practices. Despite all these odds, the country has been thriving well in its cereal and other crop food production. The current challenge is to maintain this growth in the well-endowed areas and use the natural resilience of soils to establish sustainable production in the unimproved and degraded systems in the face of the continuous population increase. Soil resilience is the result of different fluxes. These include the following.

1. Atmospheric: Radiation, heat, and precipitation
2. Endogenic soil fluxes: Weathering, soil formation, synthesis and decomposition of organic matter, accumulation, leaching and redistribution of compounds, erosion, oxidation–reduction, release and fixation of nutrients, and so on
3. Exogenic (anthropogenic) mass and energy fluxes: Effects of agricultural operations such as tillage and the like, application of chemicals, irrigation, drainage, crop removal, and so on, contamination by industrial output and radioactive fission products, among others

It is apparent that both the endogenic and exogenic fluxes are equally important in the context of Bangladesh. Due to population pressure, the land–person ratio has been squeezed and it stands at only 0.05 ha. With such a

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situation, how could someone expect our soils to remain resilient or behave as such? The cropping intensity in Bangladesh now stands at 181. For increased CI enhanced rates of fertilizer and agrochemicals are being used. It is quite obvious that nonuse of chemical fertilizer has always shown a decline in crop production. This means our soils are not resilient. Some people have a wrong notion that our soils are fertile or resilient, when in reality they are not. Factors including temperature, radiation, moisture, and the like, that are determinants for plant growth are very deceiving in Bangladesh. As a result, one is always misled by the germination and quick growth of many plants/crops; this growth has no relevance to good soil fertility; without amendment, most crops do not achieve the maximum or even economic yield levels. It is a common observation that most crops respond to fertilizer application and the response in many cases is more than double compared to no application.

The areas under double and triple cropping have increased over the decades. Monocropping without rotation is also not favorable for soil resilience. It depletes the soil of some particular nutrient elements. In such a situation, the integrated plant nutrient system (IPNS) is likely to be effective in making the soil resilient. The climatic condition of the country is favorable for an increased rate of microbial activities, hence the enhanced rate of organic matter decomposition. Withdrawal or nonuse of traditional methods of organic recycling in soil such as green manuring, farmyard manuring, and the like has contributed to depletion of organic matter. The average organic matter content of Bangladesh soils, less than 1 %, is one of the poorest in the world. It is reported that in Chandina (a locality in the south of Dhaka), the organic matter that showed medium to high in the RSS report of 1965 was low to very low in the 1990 *Upazila Nirdeshika*. When organic matter depletion is so remarkable over a period of 25 years, how can one expect our soils to be resilient? The case of nitrogen and potassium is similar. There has been a very sharp decline in both nutrients over the years. Had our soils been resilient, the picture would have been different. Sulphur and zinc have also shown a similar trend. This picture is true for all types of soils: highland, medium highland, or medium lowland. This has been the outcome despite the fact that 172 kg of nutrients/ha/yr are added in the form of chemical fertilizer. This is due to the fact that the nutrient mining is between 250 and 350 kg/ha/year. There is a negative balance for N and K for all crop sequences and for P a very small positive balance (less than 50 kg/ha/year) is obtained. The difference could be minimized through IPNS. On the other hand, in the Chandina area again, the P level has shown a dramatic increase over the period; in all types of land, the level of P has become high to very high from an original level of medium to high. This soil build-up of P has been the result of crop intensification and anthropogenic activities. IPNS could minimize this unwanted situation. The loss of nutrients or imbalanced nutrient build-up could have been minimized had there been judicious application of organic manure. Here lies the importance of IPNS. IPNS not only will make a soil resilient, it will also be able to reduce the pressure of economic hardship on the poor farmers or the growers. The politics of fertilizer will also be minimized. That the IPNS system of soil management produces better results has been shown in various field trials (BARC 2005; see Fig. 12.1).

Even if IPNS tends towards soil resilience, how far this practice will be effective in the face of anthropogenic fluxes will always remain questionable. The recent information on soil build-up of arsenic through irrigation water or build-up of toxic heavy metals and organic chemicals through mismanagement of industrial and urban wastes definitely needs to be addressed in addition to the IPNS approach to make our soil resilient, if at all.

Land-use management and soil organic carbon management is an important phenomenon for agricultural land management and crop yields. The fertilizer *Recommendation Guide* that the BARC publishes includes fertilizer management for single and multiple cropping systems, fertilizer management in no-tillage/minimum tillage systems, fertilizer management for problem soils, fertilizer management for hill soils, soil organic matter management, and IPNS. This guide provides recommendations for individual crops as well as for various cropping patterns in all the AEZs.

One of the functions of soil classification is to use the soil information to apply it to crop agriculture through appropriate management techniques. Following this philosophy, the Soil Resources Development Institute (SRDI) took the initiative to publish the *Land and Soil Resources Utilization Guide* (LSRUG) for all 460 subdistricts of the country during 1986–2001. The mapping units in these guides have land management implications. Combining GIS and computer technology these guides are used to create resource management domains (RMD) in the country. An RMD has been defined as a uniform biophysical unit demarcated on the landscape with available land conditions and land use management. Customized software named SOLARIS (Soil and Land Resources Information System) and Web-based software known as OFRS (Online Fertilizer Recommendation System) have been developed to provide a different type of service to the beneficiaries including a crop suitability assessment and crop-specific fertilizer recommendations for grassroot-level agricultural development. This software generates location-specific fertilizer recommendations for selected crops, utilizing the national nutrient database (using semi-detailed soil survey data) developed by SRDI (Imamul Huq and Hoque 2012).

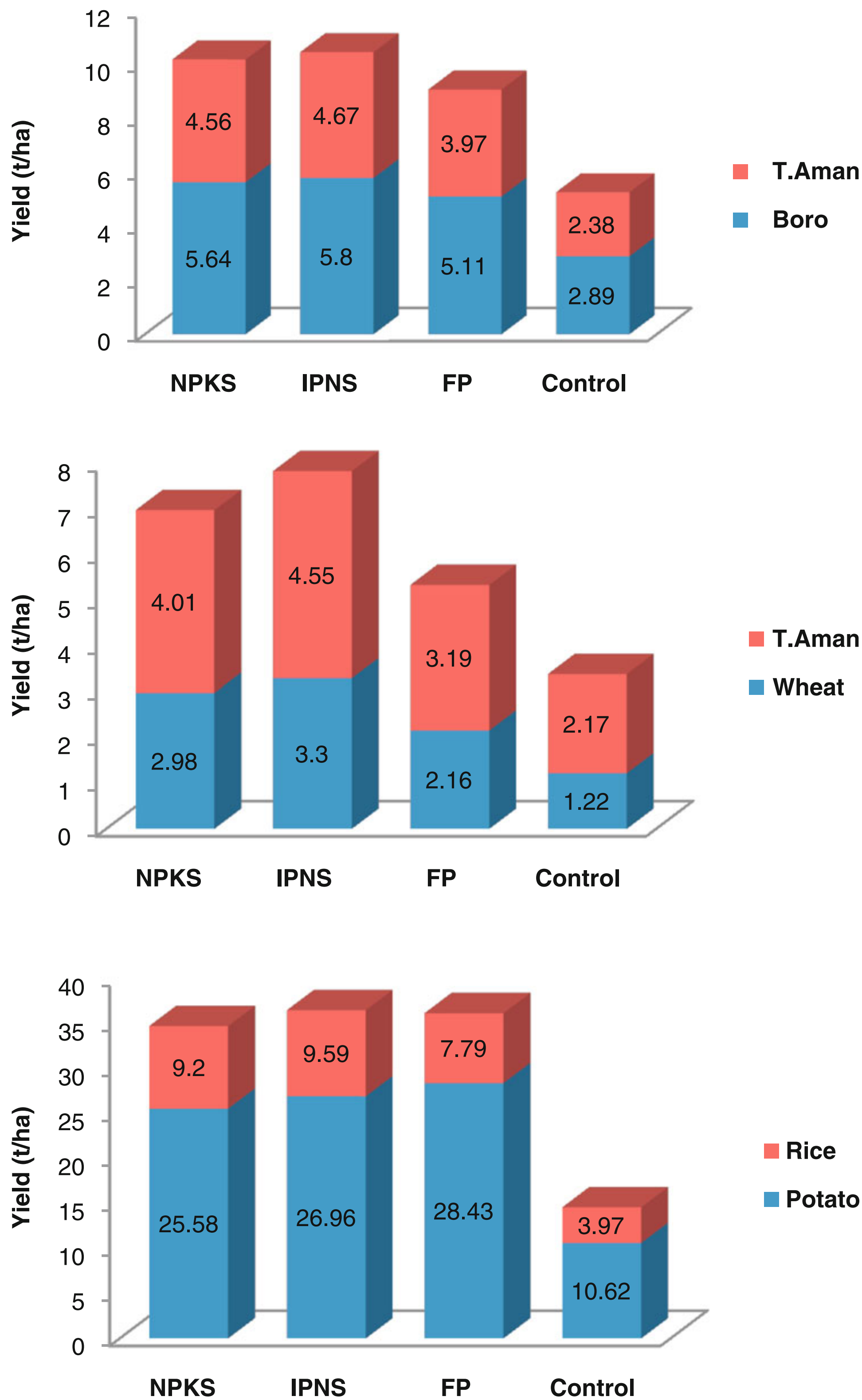

Fig. 12.1 Yield of different crops under different management systems (*source* BARC 2005)

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13 Soils and Humans

Man is dependent on good soils and good soils depend on how human beings use them. It has been mentioned in a previous chapter that the land use in Bangladesh has evolved through natural forces as well as human needs. Cultivated land, forestland, and settlements and homesteads are the major land use types in Bangladesh. With the growing population, and their increasing needs in various sectors, land use patterns are undergoing a qualitative change in which the areas under the net cropped land and forestland are gradually shrinking. A large part of the forestland is now under different types of nonforest land use such as shrimp culture, unauthorized occupation for homesteading, establishment of industrial units, urban superstructures, and so on.

There are no governmental regulations on land use and development at the national level except on forestland. The Ministry of Land Administration and Land Reforms deals with land acquisition and land development and administers the existing laws on the subject. The relevant authorities under this ministry have been directed to exercise the utmost economy in the use of land and prevent the waste and misuse of agricultural land for urban projects. Bangladesh with an estimated population of about 162 million is presently Asia's fifth and the world's eighth most populous country. Even though the population growth rate has fallen from 3 % per annum during 1973–1978 to presently about 1.39 % p.a., the population is expected to grow by another 40 % by midcentury, to 222 million, and finally stabilize around 240 million several decades after. The rural population (about 73 %) is projected to remain around 140 million by 2025, mainly due to rural to urban migration and the urban population will continue to increase. The urban population currently constitutes one-third slum and two-thirds nonslum populations; however, the slums are growing at twice the rate (5 % p.a.) of the overall urban growth rate (2.5 % p.a.) implying that the slums will account for a rapidly increasing proportion of urban dwellers thereby putting stresses on the soil and environment. In 1961, slightly more than 5 % of the population lived in the urban areas. Over the last decades, Bangladesh has experienced an extremely high rate of urbanization exceeding more than two to three times that of the national population growth rate (Choudhury 2008).

This rapid urbanization in Bangladesh is perhaps inevitable in a globalized market economy without a national system having minimum control over the development process. The conflict of development and inequality is not to be easily resolved in the country's existing political, social, and economic system. Pressure on land has been on the increase over the last three decades due to the increase in population, increased number of farm holdings due to inheritance and subdivision, expanding urbanization (12 million in 1984 and 35 million in 2004), and due to acquisition of cultivable land for development projects for industrial, business, housing, and other nonagricultural activities. About 1 % of the arable land is declining each year due to increased urbanization and nonfarming activities in the public and private sectors. As per the Ministry of Agriculture sources, each year 82,000 ha of farmland are lost due to the setting up of factories and industrial establishments, construction of roads, highways, and other infrastructure, and private uses (MoA 2012). On the other hand, demand for food grains is rising at the rate of 1 % each year. This has become a challenge for the preservation of arable soils. The per capita availability of arable land now stands at 0.05 ha. Urbanization has already emerged as a real threat to the availability of good soil in rural and peri-urban areas. About 30 % of lands in the rural areas are covered by homesteads and other nonagricultural uses. The tendency to convert good agricultural land for nonfarming and urban uses needs to be strictly controlled (Sarker web).

With diversification of economic activities, shrimp cultivation gained momentum over the last three decades or so. Shrimp culture is mainly concentrated in the coastal areas of Bangladesh where many croplands and forests have been converted to shrimp culture fields. Brackish water is allowed into these fields and kept till the farms are abandoned. When the shrimp culture fields are abandoned they cannot easily be

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converted to croplands as the soils become highly saline. The estimated area of shrimp cultivation in the four coastal districts of Khulna, Shatkhira, Bagerhat, and Cox's Bazar is about 140,000 ha of which around 70 % are located in the greater Khulna district. Although economically profitable, the unplanned expansion of shrimp culture has created a negative impact on water quality, mangrove deforestation, and the degradation of agricultural land. The Chakoria Sundarban along the southeastern Chittagong coast has almost disappeared due to encroachment by shrimp farms.

There are instances where valuable arable lands are being degraded due to human activities. It is estimated that about 7 % of the total land area of the country is experiencing degradation due both to natural and anthropogenic causes. Use of good quality agricultural lands for brickfields all over the country is a vivid example of this. The brick kiln is one of the principal agents of topsoil degradation. Brick kilns are destroying large areas of lands where bricks are manufactured by collecting soils from a depth of 1 to 2 m in arable lands, the extent of which in 1998–1999 was more than 5,000 ha spread all over the country. Brick burning alters the physical, chemical, and biological properties and habitats of the nearby soils. Burning of soils has been found to increase significantly the Ec values and sand content while decreasing the silt and clay content. Organic matter content as well as available N, P, K, and S content of burned soils also decreased significantly. The microbial biomass carbon has been found to decrease by over 90 % due to soil burning in a soil profile up to 100 cm depth. There are over 4,000 brickfields in the country that require soils and wood as fuel for which trees, homestead forests, and agricultural lands are being indiscriminately destroyed. When the brickfields are abandoned they cannot be easily converted to crop fields as burned soils cover the land there (Khan et al. 2007a, b; Rahman et al. 2010). So the loss of land due to brick making becomes more or less permanent. Land degradation negatively affects agricultural production to the tune of 2 % per year. It has been reported in the year 2000 that in one of the northern districts of the country production of paddy in 80 ha of land was completely destroyed due to the establishment of brick kilns (Rahman et al. 2010).

The formation of plowpan is yet another mode of soil degradation through human intervention. This is one of the most important features that develop in soils by tillage. This pan is most common in the transplanted rice fields. It usually occurs at a depth of 5–15 cm in the soil and is 305-cm thick. These pans could be so compact and impervious that they prevent the downward movement of water and plant roots. Because of the presence of plowpans, the top soil becomes saturated during irrigation or heavy rainfall and causes harm to sensitive dryland crops. Plowpan formation is prominent in the Tista, Ganges, Brahmaputra, Meghna, and Barind areas (Razia 2003).

Another anthropogenic mode of soil degradation in the country is the depletion of forest lands in the Chittagong Hill Tracts, Cox's Bazar, Madhupur forestlands, and Sundarban due to growing population pressure, migration of landless people in forest areas, shifting cultivation, illegal felling, and excessive commercial exploitation. It has been reported that more than 150,000 ac of forestland have been lost due to illegal occupation by land grabbers. In fact, widespread illegal and unauthorized occupation of prime lands owned by various organic agencies has emerged as a major problem in the country. Land grabbing by influential people of the society has been made easier because the government agencies do not have a complete list and proper record of lands owned by them. Large-scale illegal occupation of such lands, changing use of land without considering the ultimate impact on land conservation, and improper and unjustified leasing of lands to absentee non-farmers further aggravate and augment the land degradation in rural areas (Choudhury 2008).

Improper cultivation in hill slopes, terrace land, and piedmont plains is yet another human-induced land degradation. Shifting cultivation on the hills, locally known as *Jhum*, is a common practice among the tribal communities in the greater Chittagong Hill Tracts. Traditionally *jhum* cultivation is a slash-and-burn process where a certain area is cleared and cultivated for 1–2 years, and then abandoned for 5–12 years until the natural fertility of the soil comes back to a useful economic level. In recent years this traditional agricultural practice is considered the most inefficient way of using the rich forestlands. Due to the increase in the number of people in the Chittagong Hill Tracts region there is a demand for agricultural production that is putting pressure on cultivable land. As a result, the traditional regeneration time is not being followed, and the soil is losing its fertility. Table 13.1 gives an estimation of the soil loss in several areas of the Chittagong Hill Tracts.

Clearing of natural vegetation for cultivation of pineapple, ginger, and turmeric along the slopes has an ill effect, increasing soil erosion in the Sylhet and in the hilly areas of Chittagong. After 5–7 years of cultivation by this method these lands are totally degraded to an almost irreversible state, to the extent that they become practically unfit for later generations. Rubber plantations on more than 70 % of the slopes of the Sylhet and Chittagong hills lead to severe landslides during the heavy monsoon period. The population pressure and scarcity of agricultural land has caused a heavy influx of settlers from the plane lands to the unprotected forestlands of the Madhupur and Barind Tracts and also to the northern piedmont plains. The topsoil of all these areas is either laid over infertile loamy soils of shallow depth or over heavy compact clays. Clearing of forestland for settlements and unscientific land management for agricultural use accelerate erosion of the topsoil with the runoff

Table 13.1 Land degradation (soil loss) due to shifting cultivation

Location	Predominant slope	Soil loss (t/ha/year)
Khagrachhari	60 % area under 60 % slope	10.10–67.00
Manikchari	46 % area under 40 % slope	12.00–120.00
Ramgarh	48 % area under 40 % slope	7.00–27.00
Rangamati	53 % area under 40 % slope	26.00–68.00
Raikhali	49 % area under 40 % slope	53.00–27.00
Bandarban	58 % area under 60 % slope	8.00–107.00

Source Farid et al. (1992)

from high monsoon rains. In addition, the infertile heavy compact clay is exposed to the surface as a result of the removal of topsoil.

One of the most important causes of land degradation specifically in the Barind Tract is overexploitation of biomass from cultivated fields. The acute energy crisis in various areas leads to all available vegetation being scavenged for firewood and fodder. Due to the reduction of vegetative cover from this withdrawal of biomass, silty loam topsoil over low permeability compact heavy clay is lost and the topsoil thus has an inadequate water conservation capability. Therefore, there is considerable runoff due to heavy rainfall during the monsoon. This process of land degradation is also common in other highland and medium highland areas.

Mining of sand from agricultural land is common along the eastern side of the Dhaka–Chittagong Road, from Comilla to near Sitakunda, and in the northern piedmont areas of the northern Netrokona district. Farmers tend to enjoy the immediate monetary benefit and lease out their land for extracting sand, which is used in glass manufacturing industries or as building material. At first, more than 90 cm of topsoil are removed from the land and dumped anywhere available near the site, and then sand is extracted from a greater depth. Once the sand is extracted, the land is abandoned and no one is responsible for making the land productive again. The damage is twofold: the land purchased for dumping topsoil is used unproductively, and the land from where sand is extracted remains unutilized for many years. Extraction of pebbles from two to three feet below the surface of agricultural land is a common phenomenon in the northern part of the Greater Dinajpur and Rangpur districts. There are many similar examples of wasteful use of land. Farmers lease out or sell their land at higher prices for immediate gain, but in fact a portion of farmland is lost from their descendants, and eventually there is a loss to the national resource.

Industrial pollution is an area of growing environmental concern in Bangladesh. The country still has a relatively small industrial sector (including manufacturing, construction, mining, and utilities) contributing to about 20 % of the country's GDP. Increasing efforts are being made to stimulate the growth of local industries. As a result the industries have been growing constantly, but proper waste management has not been given due attention. Bangladesh has at present more than 30,000 industrial units, large and small. They are discharging their wastes and effluents in the natural systems in most cases without any treatment and thereby causing environmental pollution especially due to heavy metals and organic toxins. The hazardous wastes and effluents are generally discharged in lowlying areas or in the vicinity of the industrial installations. The toxic heavy metals discharged from industries in Bangladesh are cadmium, lead, chromium, mercury, zinc, arsenic, and in a few cases copper and manganese. Industries such as tanneries, paper and pulp, textiles, carbides, pharmaceuticals, pesticides, and distilleries, among others discharge heavy metals with their effluents and wastes. The heavy metals that are present in the effluents may enter growing crops from contaminated soils (Imamul Huq 2000; Miah et al. 2010). On the other hand, it has been observed that peri-urban lands and lands along highways are contaminated with heavy metals through vehicular emission; application of pesticides, herbicides, or insecticides; the presence of heavy metals in fertilizers as impurities; application of sewage sludge; faulty irrigation water; and so on that cause an elevated level of accumulation of heavy metals including Cr, Cd, Pb, Ni, Cu, Zn, and the like. Improper disposal of city and municipal wastes has also been found to degrade valuable agricultural lands (Imamul Huq et al. 2000; Hossain et al. 2010).

At present arsenic is to be considered the single most important contaminant in Bangladesh soils. The source of is the groundwater. The depth of As-laden groundwater is variable depending upon the depth of the layers containing oxidizable–reducible As-containing minerals. Soils irrigated with As-laden water are being contaminated with the element. Accumulation of As on the upper horizons is also likely to occur through the capillary rise of water during dry periods. Although the average values obtained for As in soils are less than 10 mg/kg, values as high as 80 kg/ha have also been obtained from regions where groundwater irrigation is practiced. The annual build-up through irrigation in the soil has been calculated to be 5.5 kg/ha. Arsenic accumulation has been found to be elevated in crops including rice and vegetables receiving irrigation with As-contaminated water. It has been identified that a vast area in the Ganges–Meghna–Brahmaputra catchment has emerged as the single largest arsenic-contaminated region in the world (Imamul Huq 2008; Imamul Huq et al. 2003).

The largest share of As-contaminated groundwater goes to irrigation, and 85 % of extracted groundwater is used for irrigation. About 40 % of the net cultivable area of the country is under irrigation and of the total irrigation

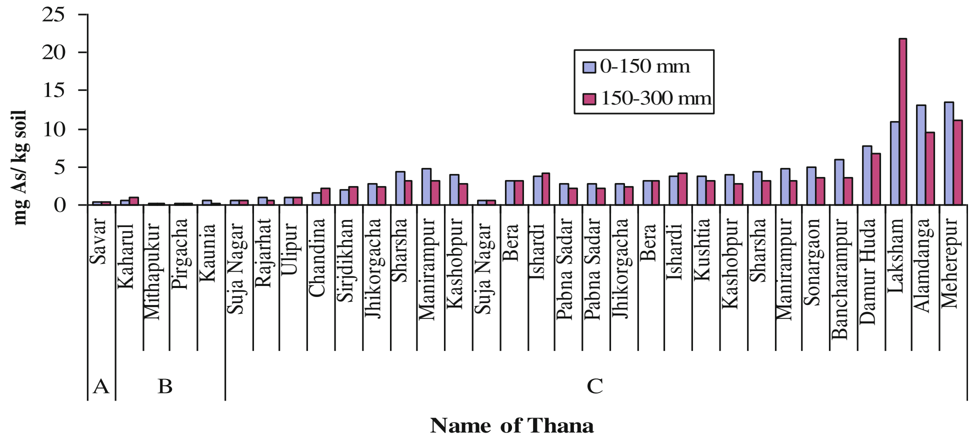

Fig. 13.1 Soil arsenic at two depths in Pleistocene (*A*), Tista (*B*), and Gangetic (*C*) alluvia (*source* Imamul Huq et al. 2003)

requirements, 60 % is fulfilled from groundwater. The major recipient of the irrigation water is boro rice along with wheat and some other vegetable crops. The most severely contaminated districts lie in the north central, southeastern, and southwestern regions of the country. In general, the southern half of the country is more contaminated than the northern half. Among the geomorphologic units of the country, the Chandina deltaic plain in southeast Bangladesh is the most severely contaminated, whereas the Pleistocene Tracts are not contaminated at all. Most of the Ganges Delta is also contaminated. The Tista fan in the northwest is either not or very feebly contaminated. Information on soil As indicates that there is a slow build-up of arsenic in many arsenic-affected areas, particularly where As-contaminated groundwater is used for irrigation. The affected soils of the Tista alluvium showed relatively lesser As in them compared to the affected soils of the Gangetic and Meghna alluvium. Figure 13.1 bears testimony to it (Imamul Huq 2008).

It is thus apparent that although the origin of arsenic in Bangladesh is geogenic, the soils are, however, being degraded due to human intervention. Soil degradation by arsenic accumulation through irrigation could be further compounded when the As-laden filter sludge (used for filtering As-contaminated groundwater) is disposed of onto agricultural lands. It has been observed that the arsenic contained in the sludge is released in the soil and enters into the growing crops (Imamul Huq et al. 2011). It is high time that one takes care to minimize human intervention and slow the process of soil degradation.

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14 Future Soil Issues

Soil in Bangladesh is a very limited but important natural resource. Due to the agrarian nature of the society, the soils of Bangladesh have been overexploited. Management of the soil resource base is of the utmost importance for ensuring optimal production. So far, the increase in crop production has largely been through crop intensification that includes use of HYV/modern varieties of crops, use of chemical fertilizers, irrigation, and agrochemicals. It is quite difficult to sustain increased production over a long period without crop extensification. Unfortunately this possibility in Bangladesh is bleak unless there is a program for land accretion in the coastal areas. Although crop production has increased due to the intensification of cultivation, the sustainability of increased crop production might not keep pace with the increasing population as there is a stagnation of crop production or even a decline, even after application of the recommended dose of fertilizers due to the depletion of organic matter. So, it is important that good agricultural land be managed with appropriate agronomic practices and the conversion of good agricultural land must be protected.

It has been estimated that unless some regulatory mechanism is enforced, infrastructure might consume about 40 % of land by 2025 at the current rate of 20 % land decline in the country. During the 1980s only 15 % of the land was under nonagricultural use but by 2006 it stood at more than 30 %. During the last few years an intensive rural road network has been constructed. Road alignment in many cases passed through field boundaries resulting in the meandering of the roads. Consequently, the actual road length became much longer than the effective length and borrow pit. Such roads have created drainage congestion resulting in delayed cultivation of early Rabi crops such as lentil, onion, garlic, wheat, mustard, and the like. To maintain the height of the road above flood level a considerable amount of agricultural land is consumed. Rapid expansion of roads and highways also consumes a significant amount of agricultural land. Settlements in newly accreted fragile charland cause topsoil erosion. High-yielding profitable crops remove high soil nutrients (Choudhury 2008).

To contain land degradation, sustain agricultural production, and maintain soil health, the issues to be considered for the future include: (a) a soil resource inventory that will include refining of the AEZs through detailed soil surveys at the lowest administrative level; prepare thematic maps for land use planning; assess soil degradation; and land zoning; (b) cropping system research to develop an efficient and high-intensity cropping system that is compatible with agrotechniques suited to different AEZs; better understanding of the crop–weather relationships that will serve a basis for preparing crop weather prediction models; diversification of cropping systems by inclusion of high-value crops for higher returns; (c) nutrient management research to maintain soil health; increase fertilizer use efficiency; promote utilization of indigenous resources; and evolve integrated nutrient management strategies for different cropping systems (Rahman 2003).

After several years of prolonged studies the national Land Use Policy and Rules were formulated in 2001 by the Ministry of Land and not by the Ministry of Agriculture. The land use policy stresses the importance of the best possible use and optimum utilization of land and water resources to ensure food security and higher nutritional standards, and the realization of the export potential of the agroprocessing industries and farming sector. The policy strongly discourages the present practice of allocating good farming land for nonagricultural activities such as urban development, industrial and educational projects, roads and highways, and different infrastructure projects.

To protect conversion of agricultural lands to nonagricultural purposes, the following points are worth mentioning.

- The land use policy 2001 needs to be updated and improved to accommodate changes in land utilization type and implementation of the amended land use policy has to be ensured.
- Digitized data on land utilization type (LUT) at the farm level should be developed.

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- All lands presently used for crop production should be used only for agriculture.
- Priority of land use has to be fixed based on soil and land qualities and demand of stakeholders. Agriculture should receive high priority in allocation of all naturally fertile land.
- A land zoning law should be promulgated and implemented. Through land zoning, land for different uses such as agriculture, fisheries, forestry, roads and highways, and so on should be delineated. The Soil Resource Development Institute (SRDI) completed a soil survey at the semi-detailed level and generated 459 volumes of reports with a map to scale 1:50,000. Those reports contain altogether 20,000 polygons of 5,000 mapping units representing location-specific data on soil and land qualities. This database was analyzed with predefined parameters of soil and land qualities for identifying the areas with specific potentials and those areas redefined as Zone. The major Zones are Agricultural, Urban/Settlements, Industrial, Aquaculture, Forest, and Horticultural Zones with some other secondary zones including salt cultivation areas, shrimp cultivation, vegetable growing areas, and so on. The layers of information such as land forms, depth and duration of inundation, soil texture, drainage, moisture availability, slope, and the like are analyzed in the Geographic Information System (GIS). The theme of Zones provides adequate back-up to the stakeholders and policy makers for sustainable use of land conducive to the environment. Through land zoning agricultural land, land for industries, urban and rural settlements, roads and highways, railways, forests, and aquaculture have to be delineated.
- Assessment of net cropped area needs to be reviewed as there are good amounts of land accreted in the coastal zone. On the other hand, increase of cropping intensity in some of the areas such as the Barind Tract needs to be addressed with the introduction of an irrigation system.
- Newly accreted land (the charlands) should be brought under tree cover for land stabilization. Once stabilized, the land should be released for agriculture or grazing with the necessary precautions.
- Lands in Bangladesh are used by many agencies and as such several of the ministries are involved. Linkage among land-using agencies needs to be improved.
- As described in Chap. 13, brick fields not only occupy land but also affect crop cultivation within a 1-km radius and as each brick field produces an average of 1.4 million bricks per season, affecting 2 ha of good agricultural land per year per brick field resulting into a loss of 10,000 ha of land, it is suggested that an alternative to brick as a construction material should be encouraged.
- New road construction in rural areas should be discouraged.
- Horizontal expansion of settlements, particularly in the rural areas should be discouraged. Cluster settlements should be encouraged and integrated with the Land Use Policy and Village Development Plan.

In conclusion, we may add that the Soil Survey is a cross-road. Bangladesh has a very good database on soil survey and interpretation of 1960–1970. There are remarkable changes in land use in both agriculture and nonagriculture. However, there need to be changes in the methodology and classification to harmonize with international approaches. In the 1960s the soil survey was done to meet the work of soil scientists, which had a narrow outlook to meet the need of an area in different perspectives.

Application of GIS, use of remote sensing tools, and digitized color photography, among others, have the potential to scale up the output of the survey to be used in multipurpose fields. The major focus could be

- Land use and its changes with time and space
- Aspects of land degradation
- Soil and land classification
- Soil informatics
- Geostatistics
- Nonagricultural conversion and application
- Planning and management at the farm level
- Short- and long-term carrying capacity
- Deterioration of all types of prime land, including both potential agriculture areas, hydrological (watersheds), and ecological (biodiversity) areas
- Wildlife management
- Land subject to natural hazards
- Land subject to human-induced hazard/degradation
- Risk management

All the above fields could be aided by a computerized modeling and simulation strategy. Modern cartography is now able to enhance soil mapping more efficiently than ever before.

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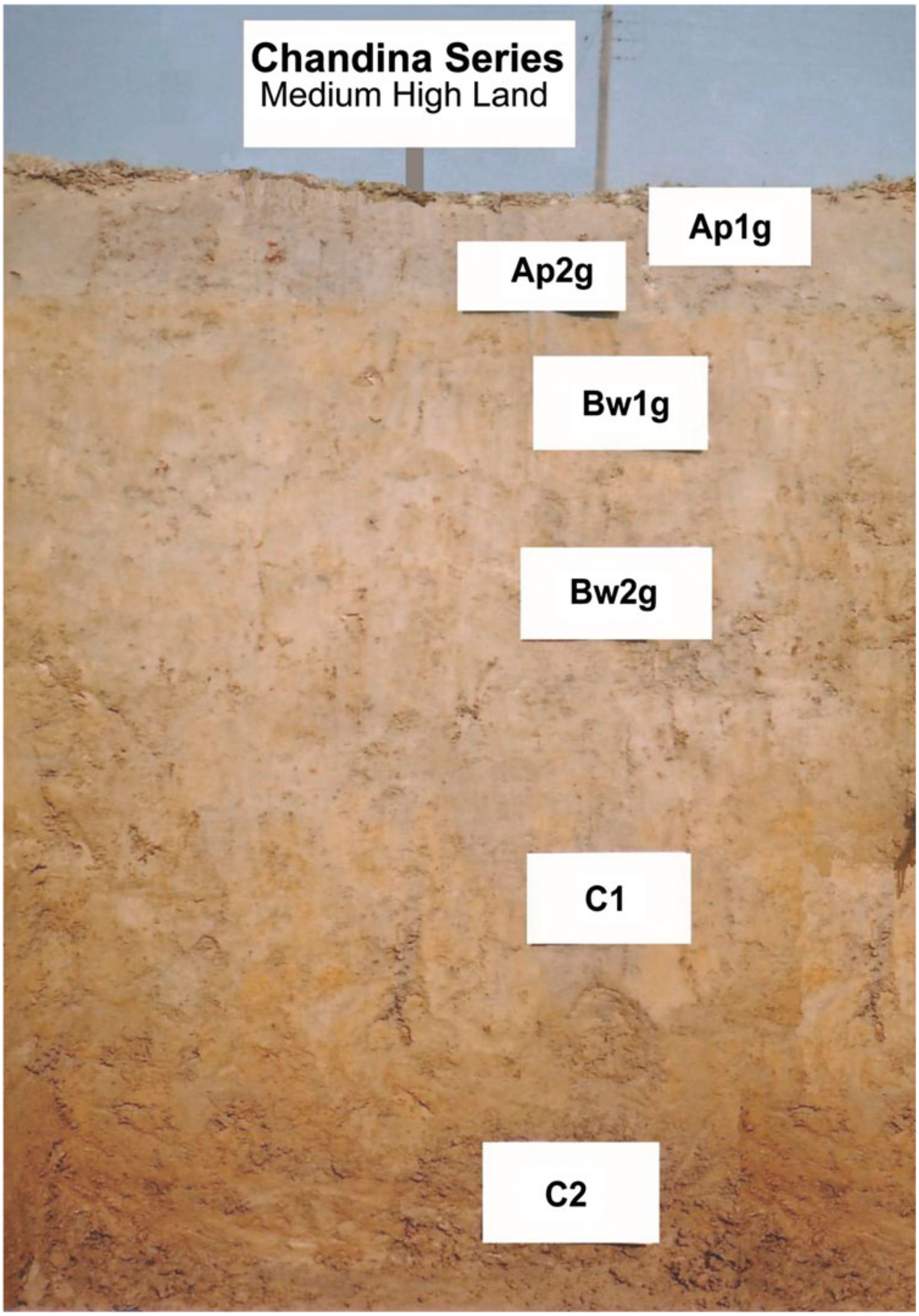
Appendix A
Soil Series: Chandina, Medium Highland Phase



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Location: Village—Ghugushal, P.S.—Shahrasti, District—Chandpur (23°15.137′N and 90°58.055′E).

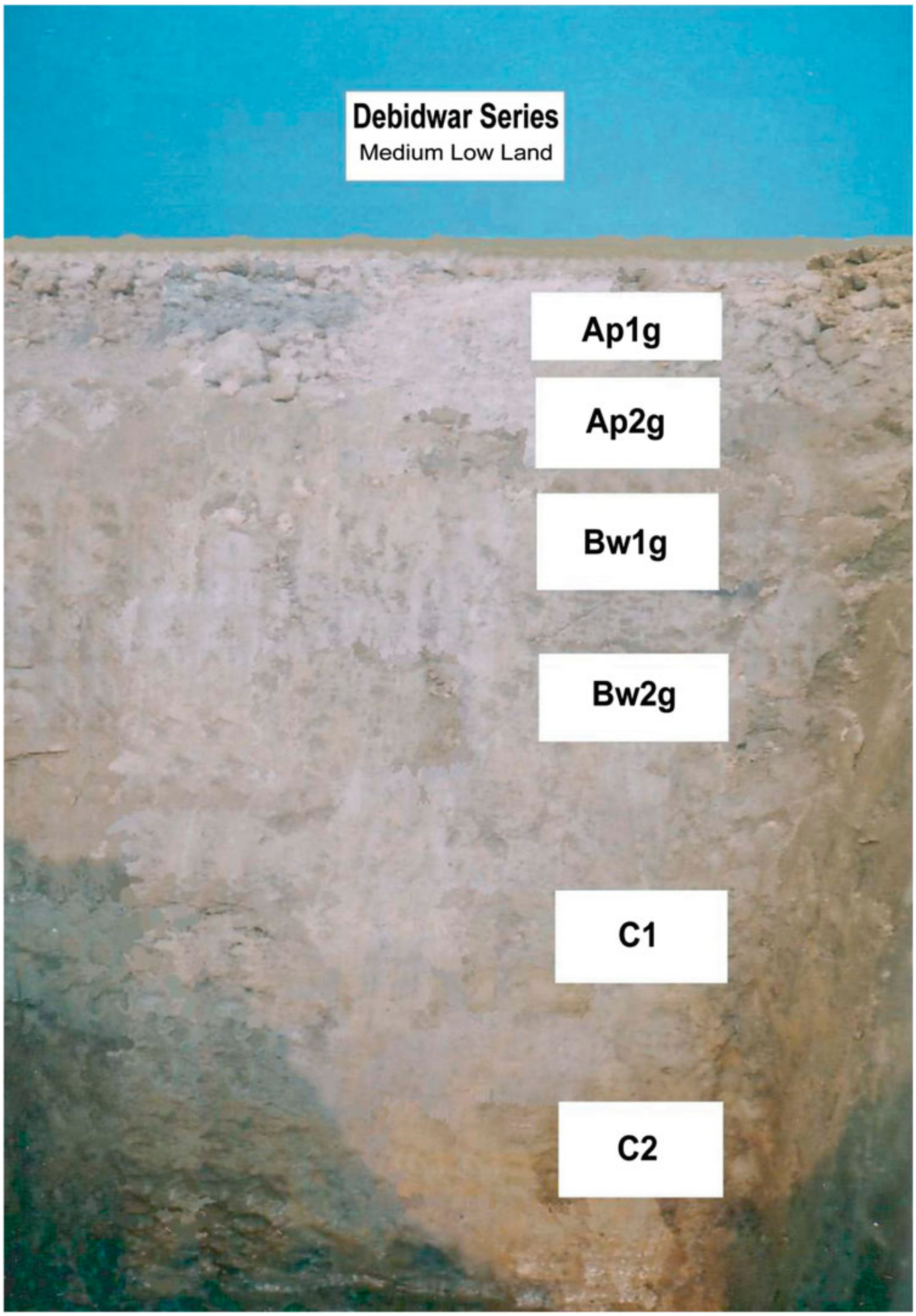
Topography: Nearly level ridge.

Land use: Boro—Transplanted Aus—Transplanted Aman.

Drainage: Poor. Flooded to 0.9 m for about 2–3 months in the rainy season.

Horizon	Depth (m)	Description
Ap1g	0–0.12	Dark grey (5Y 4/1) moist to light grey (5Y 6/1) dry; common fine distinct yellowish brown mottles; silt loam; massive; slightly sticky, nonplastic; slightly hard, dry; friable moist; many coarse tubular pores, common coarse roots; abrupt smooth boundary; pH 5.3
Ap2g	0.12–0.17	Grey (5Y 5/1) moist; common fine to medium distinct yellowish brown mottles; silt loam; weak coarse, breaking into medium to fine angular blocky; slightly sticky, nonplastic; friable moist; common fine tubular pores; few fine roots; abrupt smooth boundary; pH 5.4
Bw1g	0.17–0.36	Olive grey (5Y 5/2) moist; many fine faint olive, many fine distinct light olive brown and common fine faint grey mottles; silt loam; weak coarse, breaking into medium to fine angular blocky; slightly sticky, nonplastic, friable moist; thin grey cutans on vertical ped faces; common fine tubular pores; abrupt smooth boundary; pH 6.3
Bw2g	0.36–0.60	Olive grey (5Y 5/2) moist with common medium distinct light olive brown and common fine distinct yellowish brown mottles; silt loam; weak coarse and medium, breaking into medium to fine angular blocky; slightly sticky, nonplastic; very friable moist; thin cutans on vertical ped faces; pores and roots not recorded; abrupt smooth boundary; pH 7.1
C1	0.60–0.90	Olive (5Y 5/3) moist with common fine distinct yellowish brown mottles; silt loam; weak coarse to medium angular and subangular blocky; nonsticky nonplastic; very friable moist; broken grey cutans along cracks; pores not recorded; clear smooth boundary; pH 7.4
C2	0.90–1.20+	Olive (5Y 5/3) moist with common fine distinct yellowish brown and few fine distinct light grey mottles; silt loam; weak very coarse angular blocky; very friable moist; pores not recorded; pH 7.4

Appendix B
Soil Series: Debidwar, Medium Highland Phase



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Location: Village—Noagaon, P.S.—Shahrasti, District—Chandpur (23°12.818′N and 90°57.215′E).

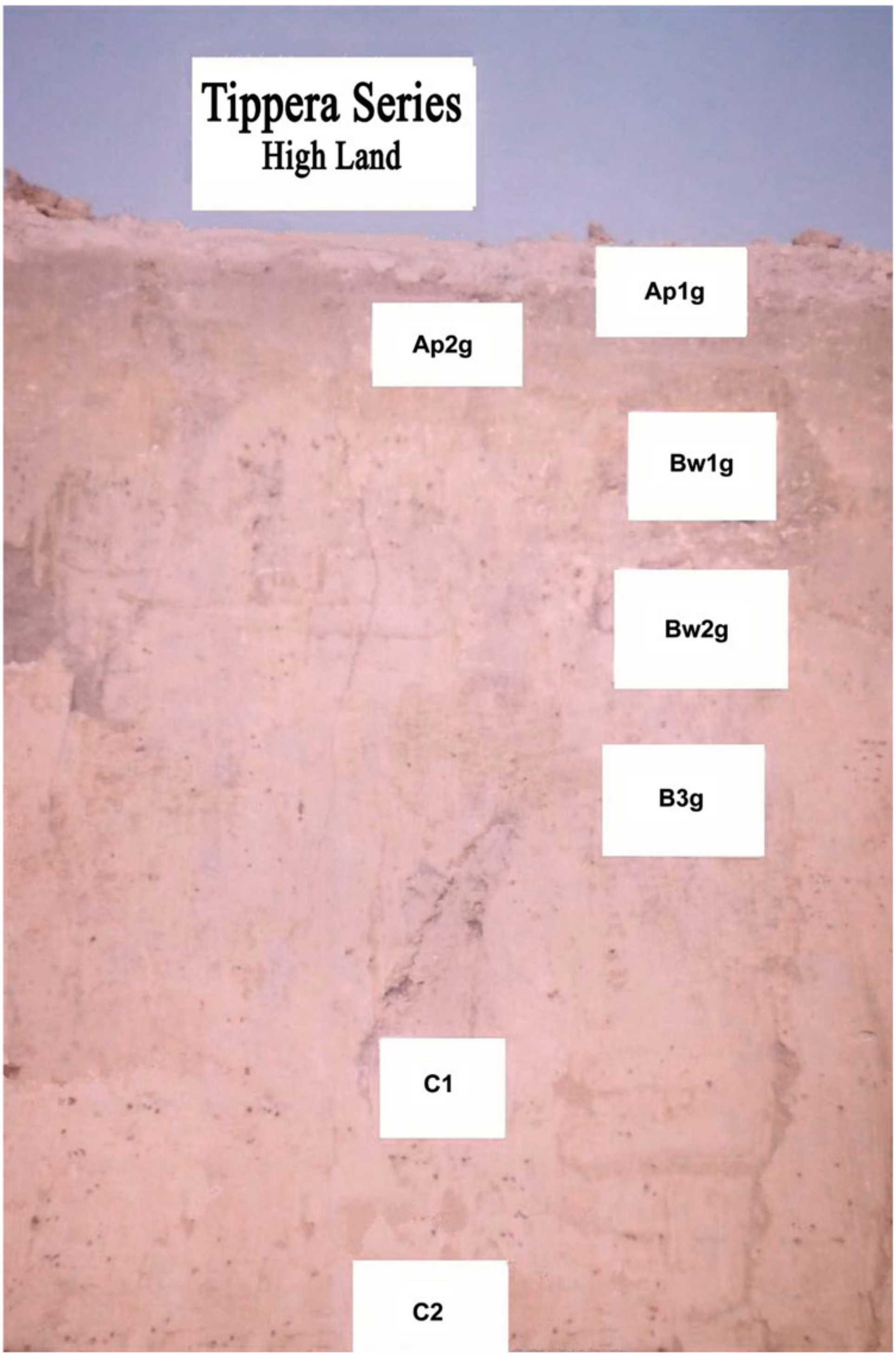
Topography: Level basin.

Land use: Boro—Fallow—Broadcast Aman.

Drainage: Poor. Flooded to between 0.9 and 1.8 m for about 4–5 months in the rainy season.

Horizon	Depth (m)	Description
Ap1g	0–0.10	Grey(5Y 5/1) moist with few fine distinct strong brown and dark yellow- wish brown mottles along root channels; silty clay; massive breaking into very coarse to coarse angular clods; firm moist; common fine tubular pores; common medium and many fine roots; abrupt smooth boundary; PH 5.2
Ap2g	0.10–0.15	Grey (5Y 5/1) moist; common fine distinct yellowish brown few fine distinct yellowish and few fine distinct light olive brown mottles; silty clay; massive breaking into medium to fine angular blocky; slightly sticky, slightly plastic; firm moist; common fine tubular pores; common fine roots; abrupt smooth boundary; pH 5.6
Bw1g	0.15–0.35	Olive grey (5Y 5/2) moist; many fine faint olive, many fine distinct light olive brown and common fine faint grey mottles; silty clay; weak coarse, breaking into medium to fine angular blocky; slightly sticky, slightly plastic. firm moist; thin grey cutans on vertical ped faces; common fine tubular pores; few fine roots; abrupt smooth boundary; pH 6.4
Bw2g	0.35–0.60	Mixed grey (5Y 5/1) and olive-yellow (10RY 6/8) (10YR 6/8) moist; silty clay loam; strong very coarse to coarse prismatic breaking into strong very coarse to coarse angular blocky; firm moist; continuous thick grey cutans on vertical and horizontal pod faces and along pores; patchy thin grey silt cutaris on pod faces; common fine and medium pores; patchy thin grey silt cutaris on pod faces; common fine and medium pores; few fine roots; clear wavy boundary pH 7.0
C1	0.60–0.88	Olive (5Y 5/3) moist with common medium distinct dark yellowish brown and distinct dark grey mottles; silty clay loam; moderate very coarse prismatic; firm moist; broken moderately thick dark grey cutans on vertical pod faces and along pores; light grey silt patches along peds; few medium tubular pores; roots not recorded; gradual smooth boundary; pH 7.4

Appendix C
Soil Series: Tippera, Highland Phase



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Location: Village—Ashrafpur, P.S.—Kachua, District—Chandpur (23°16.825′N and 90°57.287′E).

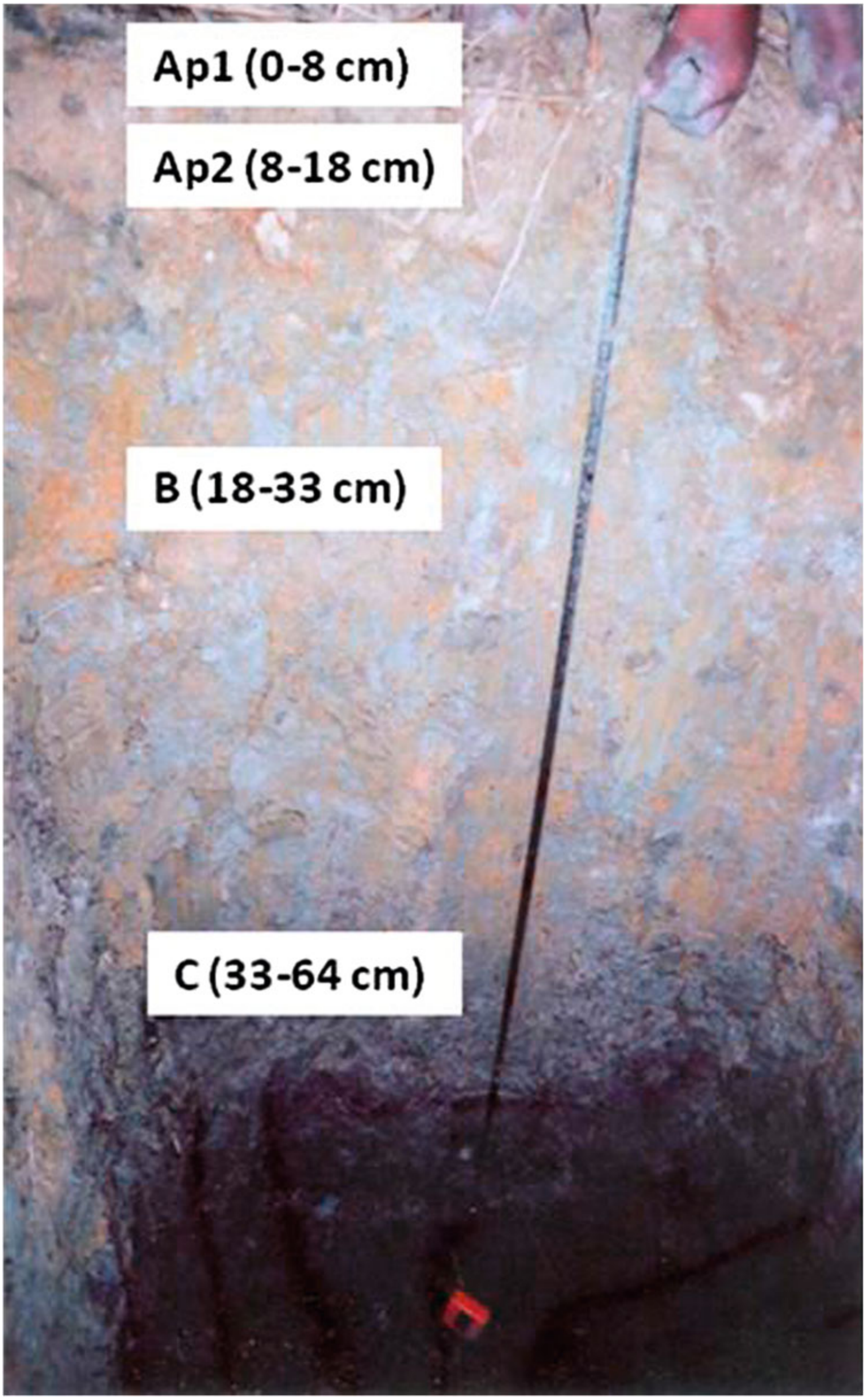
Topography: Very gently undulating to nearly level ridge.

Land use: Rabi crops (Wheat/Chili)—Transplanted Aus—Transplanted Aman.

Drainage: Imperfect. Above normal flood level. Aman paddy is transplanted by constructing bunds around the land for retaining rainwater.

Horizon	Depth (m)	Description
Ap1g	0–0.10	Very dark grey (5Y 3/1) moist to grey (5Y 5/1) dry; common fine distinct light yellowish brown and distinct yellowish brown mottles; silt loam; massive; slightly sticky, non-plastic; hard dry, friable moist; many coarse tubular pores, common coarse roots; abrupt smooth boundary; pH 5.1
Ap2g	0.10–0.14	Grey (5Y 5/1) moist; common medium distinct yellowish red mottles; silt loam; massive; nonsticky, slightly plastic; friable moist; common fine tubular pores; common fine roots; clear smooth boundary; pH 5.5
Bw1g	0.14–0.29	Olive grey (5Y 5/2) moist; many fine faint olive, many fine distinct light olive brown and common fine faint grey mottles; silt loam; moderate very coarse prismatic; slightly sticky, slightly plastic. firm moist; broken thin grey cutans along vertical ped faces; common fine tubular pores; clear smooth boundary; pH 6.6
Bw2g	0.29–0.40	Olive grey (5Y5/2) moist with common medium distinct light olive brown and common fine distinct yellowish brown mottles; silt loam; moderate coarse and medium prismatic; friable moist; broken moderately thick dark grey to grey cutans on vertical ped faces and along pores; common fine tubular pores; few fine roots; gradual smooth boundary; pH 7.0
B3g	0.40–0.64	Olive grey (5Y 4/2) moist with few fine faint light olive brown mottles; silty clay loam; moderate coarse prismatic; friable moist; broken grey cutans on vertical ped faces and along pores; common fine tubular pores; clear smooth boundary; pH 7.4
C1	0.64–0.88	Light olive brown (2.5Y 5/6) moist with common medium distinct yellowish brown mottles; silt loam; weak very coarse prismatic; friable moist; continuous thick dark grey cutans on vertical ped faces; pores not recorded; clear smooth boundary; pH 7.8
C2	0.88–1.20+	Olive (5Y 5/3) moist with common medium distinct yellowish brown and few fine distinct light grey mottles; silt loam; weak very coarse angular blocky; friable moist; pores not recorded; pH 7.8

Appendix D
Badarkhali Soil Series (Courtesy: Dr. A. Bari, SRDI)



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The Badarkhali series comprises intermittently and seasonally flooded, imperfectly to poorly drained, moderately fine-textured soils developed in the mangrove tidal floodplain. They are grey mottled brown, extremely acidic, clay loam subsoils with a moderate blocky structure.

Topography: Nearly level tidal floodplain ridge.

Land use: Transplanted aman—boro—fallow.

Drainage: Poor. Flooded to 90–180-cm deep by rainwater for 3–4 months during the monsoon season.

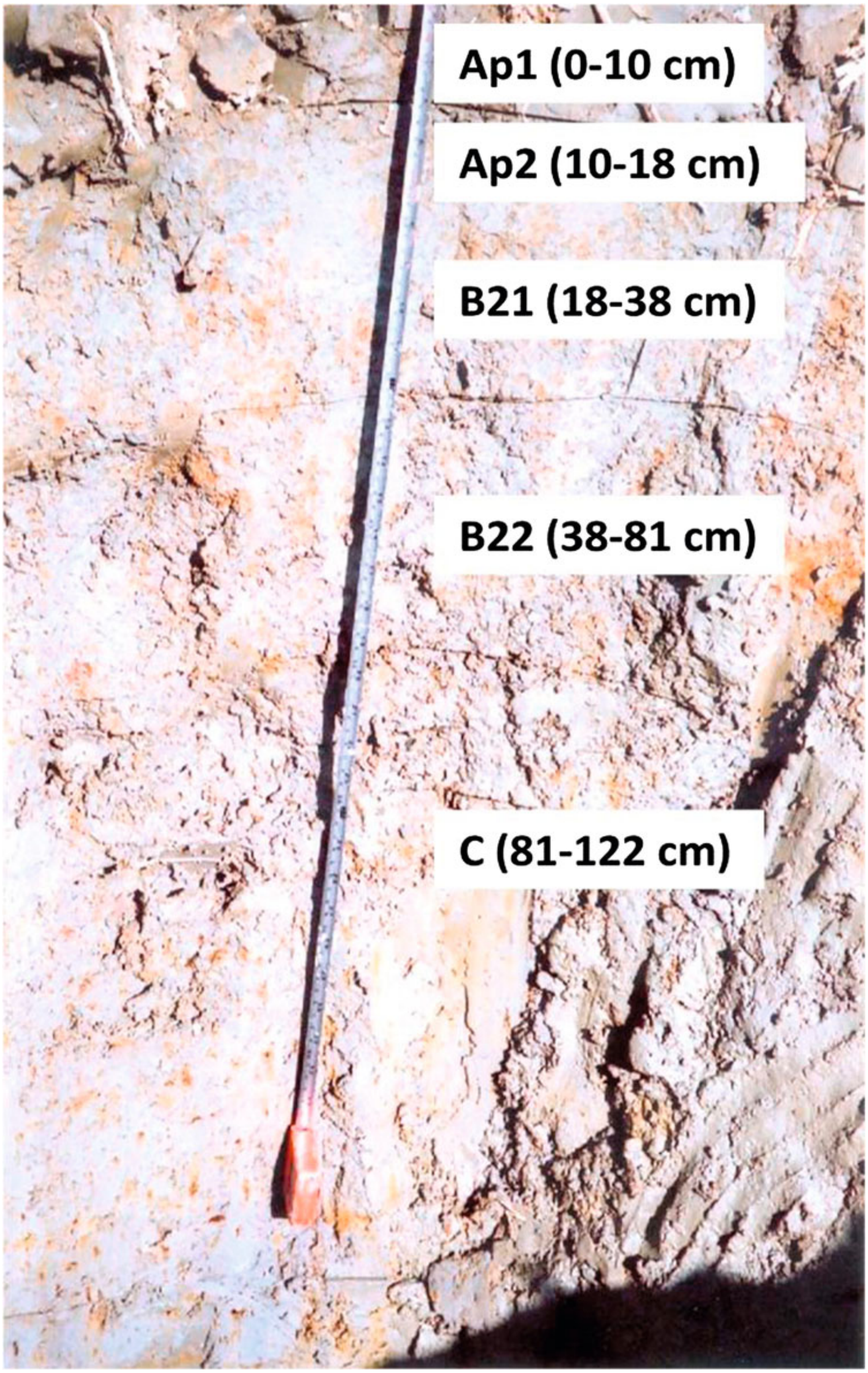
Horizon	Depth (m)	Description
Apl	0–8 cm	Grey (5Y 5/1 and 5Y 6/1) moist and dry; common fine and medium distinct yellowish brown and prominent strong brown mottles; silty clay; massive; sticky, plastic, firm moist: hard dry; very fine and fine roots; pH 4. 1; clear smooth boundary
Ap2	8–18 cm	Grey (10YR 5/1) moist; many fine and medium prominent brown, common yellowish brown mottles; silty clay-loam; massive; sticky, plastic, firm moist; patchy moderately thick grey cutans along vertical cracks; many very fine and fine tubular pores; common very fine and fine roots; pH 4.1; abrupt smooth boundary
B	18–33 cm	Grey (N6/–) moist; many fine and medium distinct yellowish brown, common distinct brown, and few fine and medium prominent brownish yellow mottles; clay loam; moderate medium and fine angular blocky; sticky, plastic, friable moist; patchy thin and moderately thick grey cutans along vertical and horizontal ped faces; many very fine and fine tubular pores; common very fine roots; pH 3.9; abrupt smooth boundary
C	33–64 cm	Grey (10YR 5/1) many fine and medium distinct dark brown mottles; clay loam; massive; moderate medium and fine angular blocky; sticky, plastic, friable moist; many very fine and fine, and few medium tubular pores; common partially decomposed roots; common yellow patches of jarosite; pH 4.1; abrupt smooth boundary

Profile characteristics: Depth to the substratum ranges from 38–62 cm. Topsoil color ranges from grey to olive-grey and texture is usually silty clay, rarely clay loam. The subsoil color generally moderate coarse and medium angular blocky, sometimes breaking into fine angular blocky having yellow patches of jarosite.

Soil Order: Inceptisols

Subgroup: Typic sulfaquepts

Appendix E
Barabakia Soil Series (Courtesy: Dr. A. Bari, SRDI)



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The Barabakia series comprises intermittently and seasonally shallowly flooded, imperfectly to poorly drained, moderately fine-textured soils developed in the tidal deposits of the mangrove tidal floodplain. They have a grey mottled yellowish brown and strong brown, silty clay subsoil with a moderate blocky structure.

Topography: Nearly level tidal floodplain ridge.

Land use: Transplanted aman—boro—fallow/salt pan.

Drainage: Poor. Flooded up to 30 to 60-cm deep by rainwater for 3–4 months during the monsoon season.

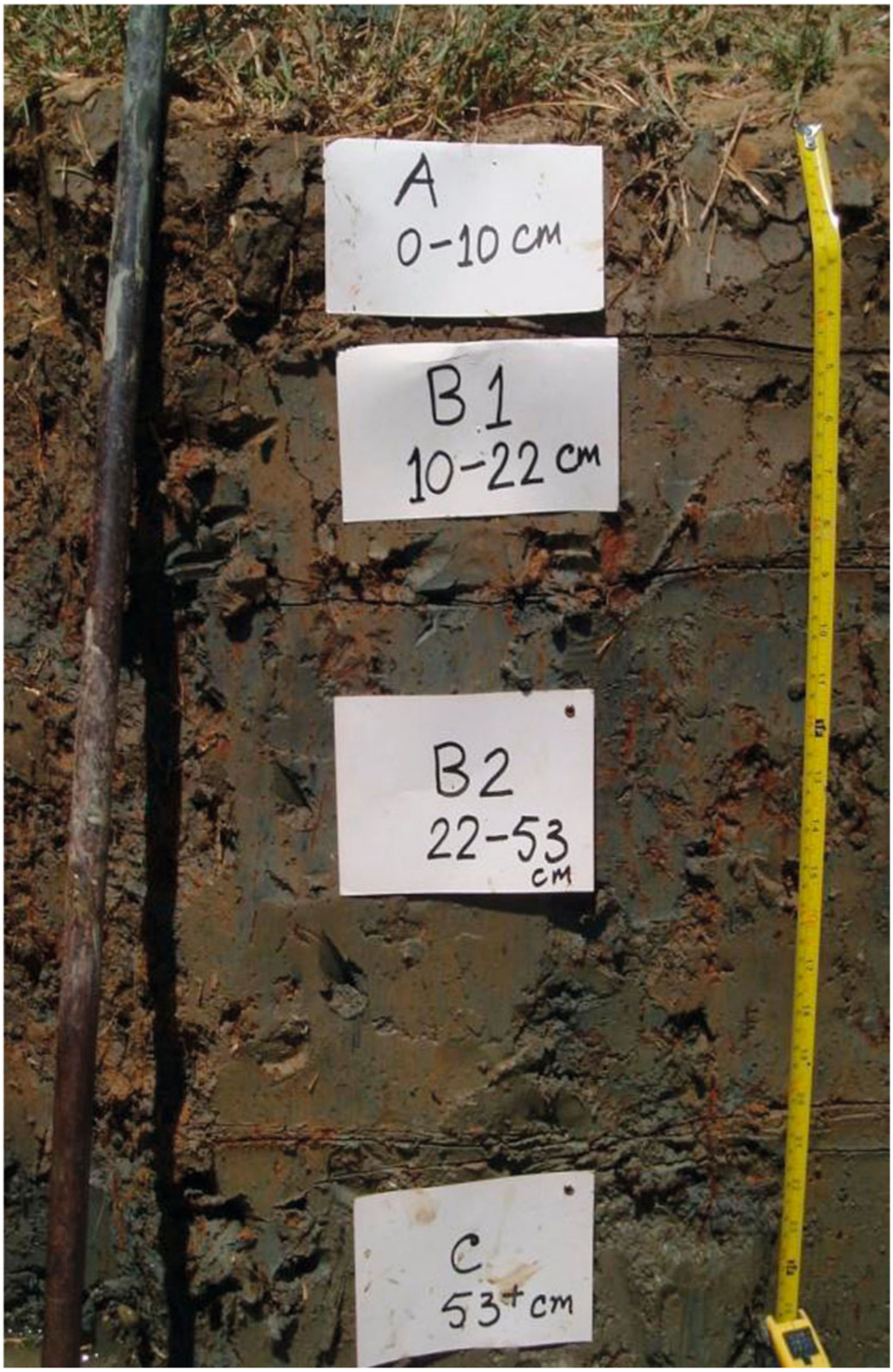
Horizon	Depth (m)	Description
Apl	0–10 cm	Grey (5Y 5/1 and 5Y 6/1) moist and dry; common fine and medium distinct yellowish brown and prominent strong brown mottles; silty clay; massive; sticky, plastic, firm moist: hard dry; very fine and fine roots; pH 4. 1; clear smooth boundary
Ap2	10–18 cm	Grey (5Y 5/1) moist; common fine and medium distinct yellowish brown and prominent strong brown mottles; silty clay loam; strong coarse and medium angular blocky; massive; sticky, plastic, very firm moist; common very fine and fine tubular pores; common very fine and fine roots; pH 6.0; abrupt smooth boundary
B21	18–38 cm	Grey (5Y 5/1) moist common fine and medium prominent dark brown and distinct yellowish brown mottles; silty clay; strong coarse and medium angular blocky; very sticky, plastic, firm moist; continuous moderately thick grey cutans along vertical and horizontal ped faces; many very fine and fine tubular pores; common very fine roots; pH 7.0; clear smooth boundary
B22	38–81 cm	Grey (5Y 5/1) moist; common fine and medium distinct yellowish brown and few fine and fine medium distinct dark brown mottles; silty clay; moderate coarse and medium angular blocky; very sticky, plastic, firm moist; continuous moderately thick and thick grey cutans along vertical and horizontal ped faces; many very fine and fine tubular pores; few yellow patches of jarosite; pH 6.0; abrupt smooth boundary
C	81–122 cm	Grey (N5/–) wet; many fine and medium distinct yellowish brown and few fine and medium distinct dark brown mottles; silty clay loam; sticky, plastic wet; pH 4.0

Profile characteristics: Topsoil color is generally grey and texture is usually silty clay loam, rarely silt loam. Subsoil color is usually grey and texture is silty clay. Subsoil structure is moderate to strong coarse and medium angular blocky. The substratum is mostly moderately fine to fine-textured and occasionally shows the presence of yellow patches of jarosite.

Soil Order: Inceptisols

Subgroup: Typic haplaquepts

Appendix F
Chakoria Soil Series (Courtesy: Dr. A. Bari, SRDI)



DOI: 10.1007/978-94-007-1128-0, © Springer Science+Business Media Dordrecht 2013

The Chakoria series comprises tidally flooded, poorly to very poorly drained soils developed in young tidal sediments of the mangrove tidal floodplain. They have a grey mottled dark brown to dark yellowish brown, raw, silt loam to silty clay loam subsoil. They are slightly to strongly saline and liable to river erosion or burial by fresh tidal deposits.

Topography: Middle part of very gently sloping mangrove tidal ridge.

Land use: Salt pan/shrimp culture.

Drainage: Very poor. Tidally flooded up to 60 to 90-cm deep during full and new moon.

Horizon	Depth (m)	Description
Al	0–10 cm	Grey (5Y 5/1) moist; common fine and medium distinct dark brown and dark yellowish brown and few fine prominent strong brown mottles; silty clay-loam; massive; sticky, plastic, firm moist: many very fine and fine roots; pH 8.5; clear smooth boundary
Bl	10–22 cm	Grey (5Y 5/1) moist; common fine distinct dark brown and few fine distinct dark yellowish brown and few fine prominent black mottles; silty clay; massive; sticky, plastic; firm moist: few partially decomposed roots; common very fine and fine roots; pH 8.5; clear smooth boundary
B2	22–53 cm	Grey (5Y 5/1) moist; common fine distinct dark yellowish brown and few fine distinct yellowish brown mottles; silty clay loam; massive; sticky, plastic; firm moist: few partially decomposed roots; pH 8.5; clear smooth boundary
C	53–127 cm	Grey (N5/–) wet; silty clay; sticky, plastic wet; few partially decomposed roots; pH 4.1

Soil order: Entisols
Subgroup: Typic haplaquents

Appendix G
Cheringa Soil Series (Courtesy: Dr. A. Bari, SRDI)

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The Cheringa series comprises seasonally flooded, poorly drained, fine-textured soils developed in the tidal deposits of the mangrove tidal floodplain. They have a grey, mottled yellowish brown to strong brown, extremely acidic, silty clay loam subsoil with a moderate to strong blocky structure.

Typical profile: Cheringa series.

Topography: Nearly level broad tidal ridge.

Land use: Transplanted aman—boro—fallow.

Drainage: Poor. Flooded up to 15 to 60-cm deep by rainwater for 5–6 months in the monsoon season and remains unsaturated for 4–5 months in the dry season.

Horizon	Depth (m)	Description
Apl	0–14 cm	Grey (5Y 5/1) and olive-grey (5Y 5/2) moist and dry; common fine and medium distinct yellowish brown and few fine prominent strong brown mottles; clay loam; massive; sticky, plastic, very firm moist, hard dry; common very fine and fine tubular pores; many very fine and fine roots; pH 5.5; abrupt smooth boundary
Ap2	14–24 cm	Grey (5y 5/1) and olive-grey (5Y 5/2) moist and dry; common fine and medium distinct yellowish brown and few fine prominent strong brown mottles; silty clay loam; massive; (plowpan); sticky, plastic, very firm moist, very hard dry; common very fine and fine tubular pores; common very fine and fine roots; pH 5.5; clear smooth boundary
B21	24–50 cm	Olive-grey (5Y 5/2) moist; many fine and medium distinct yellowish brown and common fine and medium prominent strong brown mottles; silty clay loam; moderate coarse prismatic breaking into moderate coarse and medium angular blocky; sticky, plastic, firm moist: broken moderately thick grey cutans along vertical and horizontal ped faces; many very fine and fine tubular pores; common very fine and fine roots; pH 4.1; clear smooth boundary
B22	50–74 cm	Grey (5Y 5/2) moist; many fine and medium distinct yellowish brown and common fine and medium prominent strong brown mottles; silty clay loam; moderate coarse prismatic breaking into moderate coarse and medium angular blocky; sticky, plastic, firm moist: broken moderately thick grey cutans along vertical and horizontal ped faces; many very fine and fine tubular pores; few small soft spherical iron–manganese concretions; few very fine roots; pH 3.9; abrupt smooth boundary
B3	74–100 cm	Grey (5Y 5/1) and yellowish brown (10YR 5/6) moist; many fine and medium prominent dark brown and common fine and medium distinct dark yellowish brown mottles; silty clay; moderate very coarse prismatic; sticky, plastic, firm moist; moderately thick grey cutans along vertical ped faces; many very fine and fine tubular pores; few small soft spherical iron–manganese concretions; few partially decomposed plant tissues; few very fine roots; pH 3.7; abrupt smooth boundary
Cl	100–120 cm	Grey (5Y 5/1) wet; many fine and medium distinct yellowish brown and dark yellowish brown mottles; silt loam; massive; sticky, plastic wet; broken moderately thick grey cutans along vertical ped faces; many very fine and fine tubular pores; frequent partially decomposed plant tissues; common yellow patches of jarosite; few very fine roots; pH 3.6; abrupt smooth boundary
C2	120+ cm	Grey (5Y 5/1) wet; common fine distinct dark brown mottles; loam; frequent partially decomposed plant tissues; pH 3.8

Profile characteristics: Topsoil color ranges from olive to grey and texture varies from silty clay loam to silty clay. The subsoil color ranges from grey to olive-grey and texture is usually silty, occasionally clay; the mottles color of the subsoil ranges from yellowish brown to strong brown and dark brown. Most of the profiles show the presence of yellow patches of jarosite and partially decomposed plant tissues in the lower layers.

Soil order: Inceptisols

Subgroup: Typic sulfaquepts

Appendix H
Kutubdia Soil Series (Courtesy: Dr. A. Bari, SRDI)

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The Kutubdia series includes intermittently and seasonally flooded, imperfectly to poorly drained, fine-textured soils developed in tidal sediments of the mangrove tidal floodplain occupying nearly level flat ridges and shallow basins. They have a grey, mottled yellowish brown and strong brown, firm, silty clay loam subsoil with strong prismatic and blocky structure having continuous thick grey cutans along ped faces.

Topography: Nearly level low ridge.

Land use: Salt pan/transplanted aman—fallow.

Drainage: Poor. Flooded 30 to 60-cm for 5–6 months in the monsoon season.

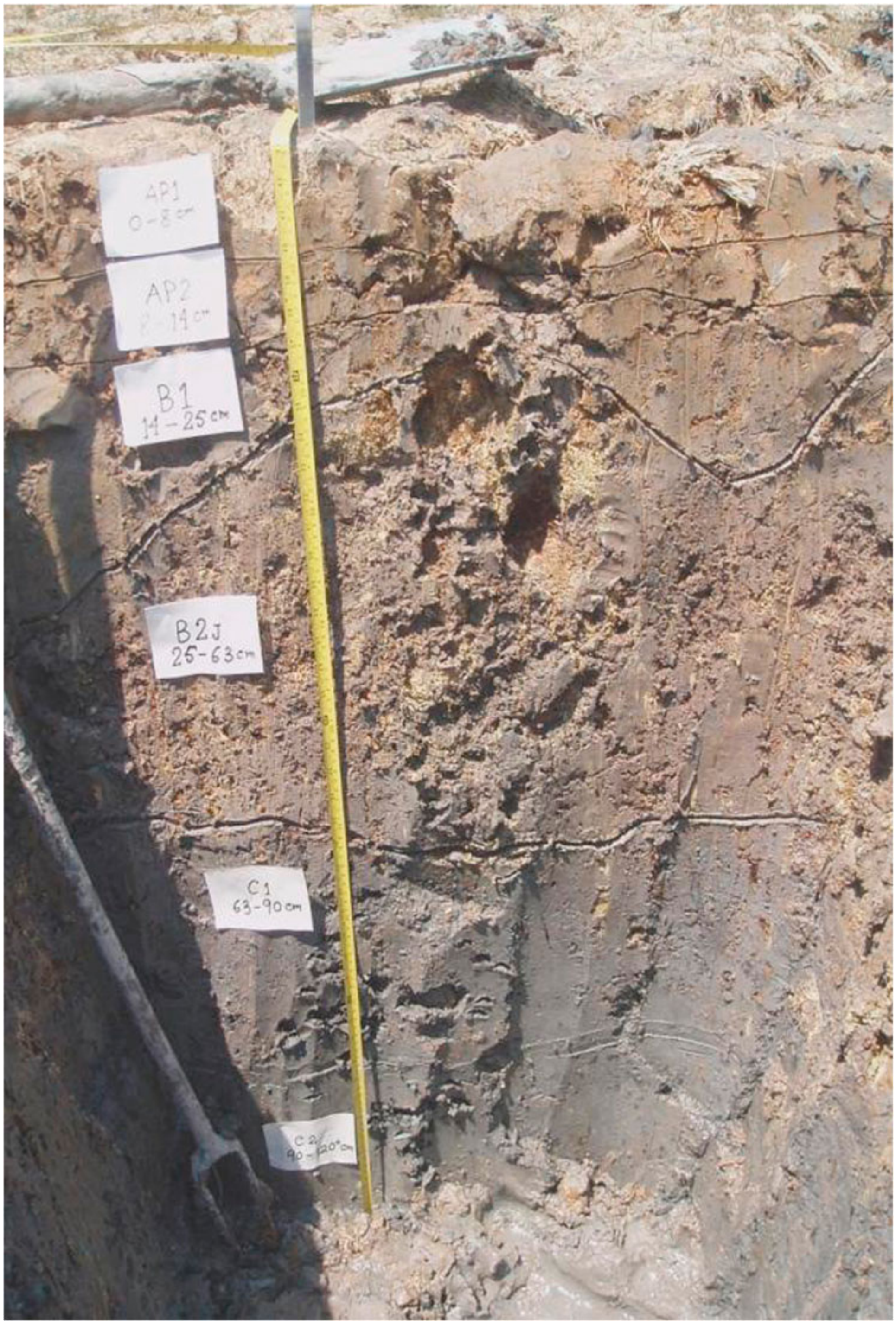
Horizon	Depth (m)	Description
Apl	0–9 cm	Grey (5Y 6/1) moist and light grey (5Y 7/1) dry; many fine distinct yellowish brown and strong brown mottles; silty clay loam; massive; slightly sticky, sticky, slightly plastic, firm moist, very hard dry; many very fine and fine tubular pores; many very fine roots; pH 6.0; abrupt smooth boundary
Ap2	9–14 cm	Olive-grey (5Y 5/2) moist; common fine and distinct dark yellowish brown mottles; silty clay loam; massive; sticky, plastic, very firm moist, few very fine and fine tubular pores; common very fine roots; pH 6.3 (7.5); abrupt smooth boundary
B1	14–33 cm	Grey (N/5–) moist; many fine distinct dark yellowish brown, common fine distinct yellowish brown and few fine distinct strong brown mottles; silty clay loam; strong coarse prismatic breaking into strong coarse and medium angular blocky; sticky, plastic, firm moist: continuous thick grey cutans along vertical and horizontal ped faces and pores; common very fine and fine tubular pores; few very fine roots; pH 5.6 (7.0); abrupt smooth boundary
B2	33–52 cm	Grey (5Y 5/1) moist; many fine and medium prominent yellowish brown and common fine and medium prominent strong brown and dark yellowish brown mottles; silty clay loam; strong coarse prismatic breaking into strong coarse and medium angular blocky; sticky, plastic, firm moist: continuous thick grey cutans along vertical and horizontal ped faces and pores; common very fine and fine tubular pores; pH 4.5 (5.0); abrupt smooth boundary
IIAlb (B21)	52–66 cm	Dark grey (10YR 4/1) moist; many fine distinct dark brown and common fine and medium distinct strong brown and yellowish brown mottles; silty clay loam; strong coarse prismatic breaking into strong coarse and medium angular blocky; sticky, plastic, firm moist; broken moderately thick grey cutans along vertical and horizontal ped faces and pores; many very fine and fine tubular pores; few partially decomposed plant tissues; pH 5.0; clear smooth boundary
IIB2b (B22)	66–94 cm	Dark grayish brown (2Y 4/2) moist; few fine distinct and many fine and medium prominent yellowish brown mottles; silty clay loam; sticky, plastic, firm moist: few partially decomposed plant tissues; few yellowish patches of jarosite; pH 4.5; abrupt smooth boundary
IIC (C1)	94–122+ cm	Grey (N/5–) moist; silty clay loam; sticky, plastic, firm moist; few partially decomposed plant tissues; pH 4.5

Profile characteristics: Depth to the substratum is variable from 30 to 90 cm. The topsoil texture is usually silty clay loam, rarely silt loam or silty clay, and the color varies from light grey to grey. The subsoil texture is usually silty clay, occasionally clay. The color of the subsoil is usually grey having yellowish brown, dark yellowish brown, and strong brown mottles; the structure is usually strong coarse prismatic breaking into strong to moderate coarse and medium angular subangular blocky having continuous to broken, thick to moderately thick, grey cutans along the vertical and horizontal ped faces and pores. Some profiles show the presence of partially silty clay or clay, rarely silty clay loam.

Soil order: Inceptisols

Subgroup: Typic haplaquepts

Appendix I
Pahartali Soil Series (Courtesy; Dr. A. Bari, SRDI)



The Pahartali series comprises intermittently and seasonally flooded, imperfectly to poorly drained, medium-textured soils developed in piedmont materials. They have a grey to olive-grey, mottled yellowish brown, dark yellowish brown, strong brown, silty clay loam or loam subsoil with a weak to moderate coarse and medium blocky structure.

Topography: Nearly level piedmont plain.

Land use: Boro—transplanted aman—fallow.

Drainage: Imperfect. Intermittently flooded by rainwater for a few days after heavy rainfall in the monsoon season. Remains unsaturated for 5–6 months in the dry season.

Horizon	Depth (m)	Description
Apl	0–8 cm	Grey (5Y 5/1 and 5Y 6/1) moist and dry; common fine and medium distinct yellowish brown mottles; loam; massive; slightly sticky, slightly plastic, firm moist, slightly hard dry; many very fine and fine roots; pH 5.4; abrupt smooth boundary
Ap2	8–14 cm	Grey (5Y 5/1) moist and dry; many fine and medium distinct yellowish brown and few fine and medium distinct strong brown mottles; loam; massive; slightly sticky, slightly plastic, firm moist, hard dry; patchy thin silt patches along cracks; many very fine and fine tubular pores; many very fine and fine roots; pH 6.3; clear smooth boundary
B1	14–25 cm	Grey (5Y 5/1) moist; many fine and medium distinct yellowish brown and common fine and medium distinct yellowish brown mottles; silty clay loam; moderate coarse prismatic breaking into moderate coarse and medium angular blocky; slightly sticky, slightly plastic, firm moist, broken thin grey cutans along vertical and horizontal ped faces; continuous thin silt patches along cracks; many very fine and fine tubular pores; common very fine and fine roots; pH 6.6; clear smooth boundary
B21	25–63 cm	Dark yellowish brown (10YR 4/4) and grey (5Y 5/1) moist; many fine and medium distinct dark brown mottles; loam; weak coarse prismatic; slightly sticky, slightly plastic, very friable moist; broken moderately thick grey cutans along vertical ped faces; many very fine and fine tubular pores; common small soft spherical iron–manganese continuous; few very fine roots; pH 6.7; clear smooth boundary
Cl	63–90 cm	Grey (5Y 5/1) moist; many fine and medium distinct dark yellowish brown and common fine and medium distinct dark brown mottles; loam; massive; slightly sticky, slightly plastic, friable moist; continuous thin grey cutans along pores; many very fine and fine tubular pores; common small soft spherical iron-manganese concretions; few very fine roots; pH 6.5; abrupt smooth boundary
C2	90–140 cm	Grey (5Y 6/1) moist; many fine and medium distinct yellowish brown and dark brown mottles; loam; slightly sticky, slightly plastic, friable moist: many very fine and fine tubular pores; common small soft spherical iron–manganese continuous; pH 6.8

(continued)

(continued)

Profile characteristics: Depth to the substratum ranges 45–90 cm. The color of the topsoil is usually grey and the texture is usually silt loam to loam. The subsoil color is generally grey, occasionally olive-grey, and the texture is usually silty clay loam or loam. The structure of the subsoil is weak to moderate coarse prismatic, breaking into weak to moderate medium and coarse blocky. There are often patchy to broken grey cutans along the vertical ped faces and pores. The substratum is mostly medium or moderately fine textured, rarely coarse textured.

Soil order: Inceptisols

Subgroup: Typic haplaquepts

Appendix J
The Crop Sequence for the 30 AEZs

Agroecological zones	Area covered	Past	Present
AEZ 1. Old Himalayan Piedmont Plain	Panchagarh, Thakurgaon, Dinajpur	Fallow–B. Aman–T.Aman	Wheat/potato/pulses–B. Aus–fallow
			Wheat/potato–B. Aus–T.Aman
		Fallow–Fallow–T.Aman	Wheat–Aus/Jute–T. Aman
			Boro–Fallow–T.Aman
			Wheat–Fallow–T.Aman
			Fallow– Sesame–T.Aman
AEZ 2. Active Tista Floodplain	Nilphamari, Rangpur, Lalmonirhat, Kurigram, and Gaibandha	Grassland	Sweet potato–aus/jute–fallow
			Fallow–millet–T.Aman
			Tobacco–aus/jute–fallow
			Wheat–aus/jute–T.Aman
		Barren land	Sweet potato–fallow–fallow
AEZ 3. Tista Meander Floodplain	Rangpur, Panchagarh, Dinajpur, Bogra, Jaipurhat, Naogaon, and Rajshahi	Rabi crop–Aus/Jute–Fallow	wheat–aus/jute–fallow
			Mustard– Aus/Jute–Fallow
			Vegetable– Aus/Jute–Fallow
		Fallow–Aus/Jute–T.Aman	Wheat–Aus/Jute– T.Aman
			Potato–Jute–T.Aman
			Tobacco–T.Aus–T.Aman
			Wheat–Fallow–T.Aman
			Boro–Fallow–T.Aman
		Fallow–B.Aman	Boro–T.Aman
AEZ 4. Karatoya-Bangali Floodplain	Bogra, Sirajganj, Pabna	Fallow–Aus/Jute–T.Aman	Wheat–jute– T.Aman
			Potato–jute–T.Aman
			Mustard–jute–T.Aman
			Vegetable– aus/jute–T.Aman
			Boro–fallow–T.Aman
			Fallow–T.Aus–T.Aman
		Rabi–B.Aus and Aman	Boro–deep water–T.Aman
		Rabi–B. Aman	Grass pea–B.Aman
		Fallow–B.Aman	Fallow–B.Aman
			Boro–fallow–fallow

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(continued)

Agroecological zones	Area covered	Past	Present
AEZ 5. Lower Atrai Basin	Naogaon, Natore, Rajshahi, small part of Bogra and Sirajganj	Fellow/Rabi Crop–Fallow–B.Aman	Boro–deep water T. Aman
			Grass pea–B.Aman
			Grass pea–B.Aus and Aman
		Fallow–B.Aman	Boro–fallow–fallow
			Fallow–boro aman–fallow
			Boro–fallow– T.Aman
AEZ 6. Lower Punarbhaba Floodplain	Naogaon, Chapai, Nawabganj	Fallow–Fallow–B.Aman	Boro–fallow–fallow
			Boro–deep water T.Aman
		Grazing land	
AEZ 7. Active Brahmaputra-Jamuna Floodplain	Kurigram, Gaibandha, Sirajganj, Pabna, Sherpur, Jamalpur, Tangail, Manikganj	Rabi crop–mixed broadcast Aus and Aman	Mustard–aus/jute–fallow
		Grassland	Groundnut
			Sugarcane
			Spices and vegetables
AEZ 8. Young Brahmaputra and Jamuna Floodplain	Sherpur, Jamalpur, Tangail, Manikganj, Dhaka, Munshiganj, Ghazipur, Mymensingh, Kishoreganj, and Narsingdi	Fallow– Aus/Jute–T.Aman	Boro–fallow–T. Aman
			Wheat/mustard/blackgram/grass pea/potato–B. Aus/jute–T.Aman
			Fallow–T. Aus–T.Aman
			Sugarcane
			Boro–fallow–fallow
		Rabi crop–mixed broadcast Aus and Aman	Wheat/mustard–B.Aus/jute–fallow
AEZ 9. Old Brahmaputra Floodplain	Sherpur, Jamalpur, Tangail, Mymensingh, Kishoreganj, Narsingdi, Dhaka, Narayanganj, and Gajipur	Fallow– Aus/Jute–Fellow	Mustard–aus/jute–fallow
			Spices and vegetables–jute–fallow
			Sugarcane
		Fallow– Aus/Jute–T.Aman	Boro–fallow–T.Aman
			Fallow–jute–T.Aman
			Fallow–T.Aus–T.Aman
			Wheat–aus–T.Aman
		Rabi crop–mixed broadcast Aus and Aman	Boro–deep water T.Aman
AEZ 10. Active Ganges Floodplain	Chapai Nawabganj, Rajshahi, Natore, Pabna, Kushtia, Faridpur, Rajbari, Manikganj, Munshiganj	Rabi crop–mixed broadcast Aus and Aman	Blackgram/wheat/onion/garlic/B.Aus/jute–fallow
		Fallow– mixed broadcast Aus and Aman	Onion/garlic/wheat/mustard/lentil–B.Aus/jute–fallow
		Grassland	Boro–fallow–T.Aman
			Fallow–B.Aus–T.Aman
			Blackgram/wheat/lentil/mustard–fallow–fallow

(continued)

(continued)

Agroecological zones	Area covered	Past	Present
AEZ 11. High Ganges River Floodplain	Chapai Nawabganj, Rajshahi, Jessore, Magura, Pabna, Kushtia, part of Khulna, Naogaon, Narail	Rabi crop–Aus/Jute–Fallow	Wheat –B.Aus/jute–fallow
			mustard– b.aus/jute–fallow
			Lentil/chickpea/cotton/ groundnut–B.Aus/jute–fallow
		Fallow– Aus/Jute–T.Aman	Wheat –B.Aus/jute–T.Aman
			Mustard– jute– T.Aman
			Chickpea– B.Aus –T.Aman
			Lentil–sesame–T.Aman
		Fallow– Fallow–T.Aman	Boro–fallow–T.Aman
			Fallow–B.Aus –T.Aman
			Lentil/chickpea– fellow–T.Aman
		Fallow–Mixed broadcast Aus and Aman	Boro–deep water T.Aman
AEZ 12. Lower Ganges River Floodplain	Rajshahi, Natore, Pabna, Kushtia, Faridpur, Madaripur, Gopalganj, part of Khulna, Manikganj, Munshiganj	Rabi crop– Aus/Jute–Fallow	Wheat/mustard– B.Aus/ jute–fallow
			Sugarcane
			Spices
			Vegetables
		Fallow– Aus/Jute–T.Aman	Wheat –B.Aus/jute–T.Aman
			Potato–B.Aus/jute–T.Aman
		Rabi crop–Mixed broadcast Aus and Aman	Chickpea–mixed B.Aus/ jute–T.Aman
		Fallow– Mixed broadcast Aus and Aman	Boro–deep water T.Aman
AEZ 13. Ganges Tidal Floodplain	Barisal, Patuakhali, Pirojpur, Jhalakati, Barguna, Bagerhat, Khulna, Satkhira	Fallow–B.Aus/Jute–T.Aman	Boro–fallow–T.Aman
			Fallow–T.Aus–T.Aman
			Fallow–sesame/shrimp–T.Aman
		Fallow–Fallow–T.Aman	Grass pea–fallow–T.Aman
			Fallow–fellow–T.Aman
		Natural Mangrove Forest	Natural mangrove forest
AEZ 14. Gopalganj-Khulna Beels	Gopalganj, Bagerhat, Khulna, Madaripur, Narail and part of Pirojpur	Fallow—B.Aus/Jute–Fallow	Chickpea– B.Aus/jute–fallow
		Rabi crop–Mixed B. Aus and Aman	Chickpea– mixed B. aus and aman
		Fallow–B.Aman	Boro–fallow–fallow
			Chickpea– B. Aman
AEZ 15. Arial Beel	Munshiganj and part of Dhaka	Fallow– Mixed B. Aus and Aman	Mustard–boro
		Fallow–B. Aman	Boro–fallow–fallow
			Chickpea– B. Aman

(continued)

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Agroecological zones	Area covered	Past	Present
AEZ 16. Middle Meghna River Floodplain	Kishoreganj, Brahmanbaria, part of Comilla, Chandpur, and Munshiganj	Fallow–Aus/Jute–T.Aman	Wheat/potato/mustard/pulses–B. Aus/jute–T.Aman
		Rabi crop–Mixed B. Aus and Aman	Mustard–boro–fallow
			Mustard/potato– mixed B. Aus and Aman
		Fallow–B.Aman	Mustard/grass pea/groundnut–B. Aman
AEZ 17. Lower Meghna River Floodplain	Chandpur, Noakhali, Laxmipur	Rabi crop–Aus/Jute–T. Aman	Boro–fallow–T. Aman
			Vegetable/onion/garlic–B.Aus/jute–T.Aman fallow–T. Aus–T. Aman
		Rabi crop–Mixed B. Aus and Aman	Mustard/potato–boro/jute–fallow
		Fallow–B. Aman	Boro–fallow–fallow
			Mustard/grass pea–B. Aman
AEZ 18. Young Meghna Estuarine Floodplain	Chittagong, Feni, Laxmipur, Bhola, Barisal, Patuakhali, Barguna	Fallow–Fallow–T. Aman	Fallow–B. Aus/sesame/T. Aus–T.Aman
		Fallow–B. Aus–T.Aman	Mustard/grasspea Vegetable/onion/garlic/chili–B.Aus/–fallow
		Rabi crop–Aus/Jute–T. Aman	Mustard/grasspea Vegetable/onion/garlic/chili–jute–T.Aman Boro–fellow–T.Aman
AEZ 19. Old Meghna Estuarine Floodplain	Comilla, Brahmanbaria, Chandpur, Feni, Noakhali, Laxmipur, Kishoreganj, Habiganj, Dhaka, Gopalganj, Barisal	Rabi crop–Aus/Jute–T. Aman	Mustard/wheat/grasspea/potato–B. Aus–T. Aman
			Boro–fallow–T.aman
			Fallow–T. Aus–T. Aman
		Rabi crop–Jute–Fallow	Mustard/wheat/grasspea–jute–fallow
			Vegetable–chili/mustard/wheat/grasspea/potato–B. Aus–fallow
		Rabi crop–Mixed B. Aus and Aman	Mustard–boro–fallow
			Mustard/grasspea– mixed B. Aus and Aman
		Fallow–B. Aman	Boro–fallow–fallow
			Mustard/grasspea–B. Aman
			Fallow–B. Aman
AEZ 20. Eastern Surma-Kushiyara Floodplain	Sylhet, Moulvi Bazar, Sunamganj, Habiganj	Fallow–B. Aus–T.Aman	Boro–fallow–T. Aman
			Mustard/groundnut–B. Aus–T. Aman
			Fallow– B. Aus–T. Aman
			Fallow–fellow–T. Aman
		Fallow–B. Aman	Boro–fallow–Fallow Fallow–B. Aman
		Grassland	Grassland
			Boro–fallow–fallow

(continued)

(continued)

Agroecological zones	Area covered	Past	Present
AEZ 21. Sylhet Basin	Sunamganj, Habiganj, Kishoreganj, Netrokona, Brahmanbaria	Rabi crop–Mixed B. Aus and Aman	Grasspea/mustard/groundnut–jute–fallow
			Grasspea/mustard/groundnut–B.Aus–T. Aman
			Boro–deep water T. Aman
		Fallow–B. Aman	Boro–fallow–fallow
			Fallow–B.Aman
		Boro–Fellow–Fallow	Boro–fallow–fallow
		Grassland	Grassland
AEZ 22. Northern and Eastern Piedmont Plain	Sherpur, Netrokona, Sylhet, Moulvi Bazar, Sunamganj, Habiganj, small part Comilla, Brahmanbaria, Mymensingh	Fallow–B. Aus–T.Aman	Wheat/potato–B. Aus–T.Aman
			Boro–fallow–T.Aman
			Fallow–T. Aus–T.Aman
			Mustard/wheat/vegetable–B. Aus–fallow
		Fallow–Jute–T.Aman	Mustard/wheat/vegetable–jute–fallow
			Boro–fallow–T.Aman
			Fallow–T. Aus–T.Aman
		Fallow–B. Aman	Boro–deep water T. Aman
		Grassland	Boro–fallow–fallow
			Grassland
AEZ 23. Chittagong Coastal Plain	Feni, Chittagong, Cox's Bazar	Fallow–Fallow–T. Aman	Mustard/wheat/grasspea/potato–fallow–T. Aman
			Boro–fallow–T. Aman
			Fallow–B. Aus–T.Aman
			Fallow–T. Aus–T.Aman
		Grassland	Boro–deep water T. Aman
			Grassland
AEZ 24. St. Martin's Coral Island	St. Martin's Island	Coconut, Beach	Coconut, beach
AEZ 25. Level Barind Tract	Dinajpur, Gaibandha, Bogra, Naogaon, Natore, Sirajganj part of Rajshahi and Nawabganj	Fallow–Fallow–T. Aman	Boro–fallow–T. Aman
			Fallow–fallow–T. Aman
			Wheat/potato–fallow–T. Aman
		Fallow–B. Aus–T.Aman	Fallow–B. Aus–T.Aman
		Grassland	Boro–deep water T. Aman
			Grassland boro–fallow–fallow
AEZ 26. High Barind Tract	Rajshahi, Nawabganj, Naogaon	Fallow–Fallow–T. Aman	Fallow–fallow–T. Aman
			Boro–fallow–T. Aman
			Fallow–B. Aus–T.Aman
			Wheat/chickpea–fallow–T. Aman
		Grassland	Fallow–fallow–T. Aman

(continued)

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Agroecological zones	Area covered	Past	Present
AEZ 27. North-eastern Barind Tract	Dinajpur, Rangpur, Gaibandha, Jaipurhat, Bogra,	Rabi crop–Aus/Mesta–Fallow	Mustard/wheat/grasspea/potato–B.Aus–Fallow
			Mustard/wheat/grasspea/Potato–Jute–Fallow
			Banana
		Fallow–B. Aus–T.Aman	Wheat–jute/aus–T. Aman
			Potato–jute/aus–T. Aman
			Potato/wheat–fallow–T. Aman
			Mustard–boro–T. Aman
		Fallow–Fallow–T. Aman	Boro–fallow–T. Aman
			Fallow–T. Aus–T.Aman
AEZ 28. Madhupur Tract	Dhaka, Ghazipur, Narsingdi, Jamalpur, Tangail, Mymensingh, Kishoreganj,	Rabi crop–Aus/Mesta–Fallow	Mustard/vegetable/groundnut–jute/aus–fallow
			Mustard/Vegetable–Mesta–Fallow
		Fallow–Aus/Mesta–Fallow	Sugarcane
			Orchard
			Pineapple
			Mustard/blackgram/vegetable–fallow–fallow
		Fellow–T. Aus–T.Aman	Boro–fallow–T.Aman
			Fallow–B. Aus–T.Aman
			Fallow–T. Aus–T.Aman
		Boro–Fallow–Fellow	Boro–fallow–fallow
			Boro–deep water T. Aman
		Forest	Forest
AEZ 29. Northern and Eastern Hills	Khagrachhari, Rangamati, Bandarban, Chittagong, Cox's Bazar, Habiganj and small parts of Moulavibazar, Sunamganj, Mymensingh, Sherpur, Comilla, Feni	Forest	Forest
		Fallow–B. Aus–T.Aman	Fallow–B. Aus–T.Aman
			Boro–fellow–T.Aman
		Grassland	Grass Rubber
		Tea	Tea
AEZ 30. Akhaura Terrace	Small part of Brahmanbaria, Habiganj	Fallow–Aus/Mesta–Fallow	Orchard
		Rabi crop–Aus/Mesta–Fallow	Vegetable
		Fallow–B. Aus–T.Aman	Boro–fallow–T. Aman
			Mustard/vegetable– B. Aus–T.Aman
			Fallow–fallow–T. Aman

B-Aus/Aman broadcast aus/aman; *T. Aman* transplanted aman

Authors' Biographies

Prof. Dr. S. M. Imamul Huq As a leading scientist of the country, Prof. Dr. S. M. Imamul Huq is involved in research on the transfer of arsenic from groundwater to the food chain. With an M.Sc. in soil science from the University of Dhaka in 1971, he received a second M.Sc. in the year 1980 from the Asian Institute of Technology (AIT), Bangkok, Thailand in agricultural soil and water engineering and obtained his D. Engg. from the University of Nancy I, France in 1984. He joined the University of Dhaka in 1973 as a lecturer in soil science and is now a selection grade professor in the Department of Soil, Water and Environment of the same university. He has been the chairman, Bangladesh Council for Scientific and Industrial Research (BCSIR) from 2009 to 2011 and of the Department of Soil, Water and Environment of the University of Dhaka from 2005 to 2008. With more than 240 publications to his credit in various international and national journals, Prof. Huq has been awarded the prestigious Bangladesh Academy of Sciences Gold Medal, and the Bangladesh UGC Award for his work on bioremediation of arsenic toxicity by algae in rice culture. He has been elected a "Distinguished Alumnus" by the AITAA 2008. Prof. Huq has been the chief editor of the *Dhaka University Journal of Biological Sciences*, joint editor of the *Journal of the Asiatic Society of Bangladesh (Science)*, member of the editorial board of the *Journal of Soil Science Society of Bangladesh*, and a reviewer of many national and international scientific journals. He is the president of the Soil Science Society of Bangladesh (SSSB) and the president of the Bangladesh Association for the Advancement of Science (BAAS). He is a fellow of the National Defense College of Bangladesh.

Jalal Uddin Md. Shoaib Jalal Uddin Md. Shoaib graduated in soil science from the Department of Soil Science, University of Dhaka in 1972. He did his post-graduate diploma on soil survey using remote sensing technology from the International Institute for Aerospace and Earth Sciences (ITC), The Netherlands in 1989. He joined as scientific officer with the Soil Resource Development Institute (SRDI), Ministry of Agriculture, Government of Bangladesh in 1976 and retired as chief scientific officer of the same department in 2009. He was involved in developing a database on soil, land resources, and utilization with special reference to land use. He became a watershed expert and established the Soil–Water Conservation and Watershed Management Center in the Hill areas of Bangladesh. He is well linked with the World Organization of Conservation Approaches and Technologies (WOCAT), International Erosion Control Association (IECA), Indian Society of Soil-Water Conservation, and the Asiatic Society of Bangladesh (ASB). He has 12 international and 19 local publications related to soil, land use, and watershed management.

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